Mid-Atlantic Climate Change: Regional Implications

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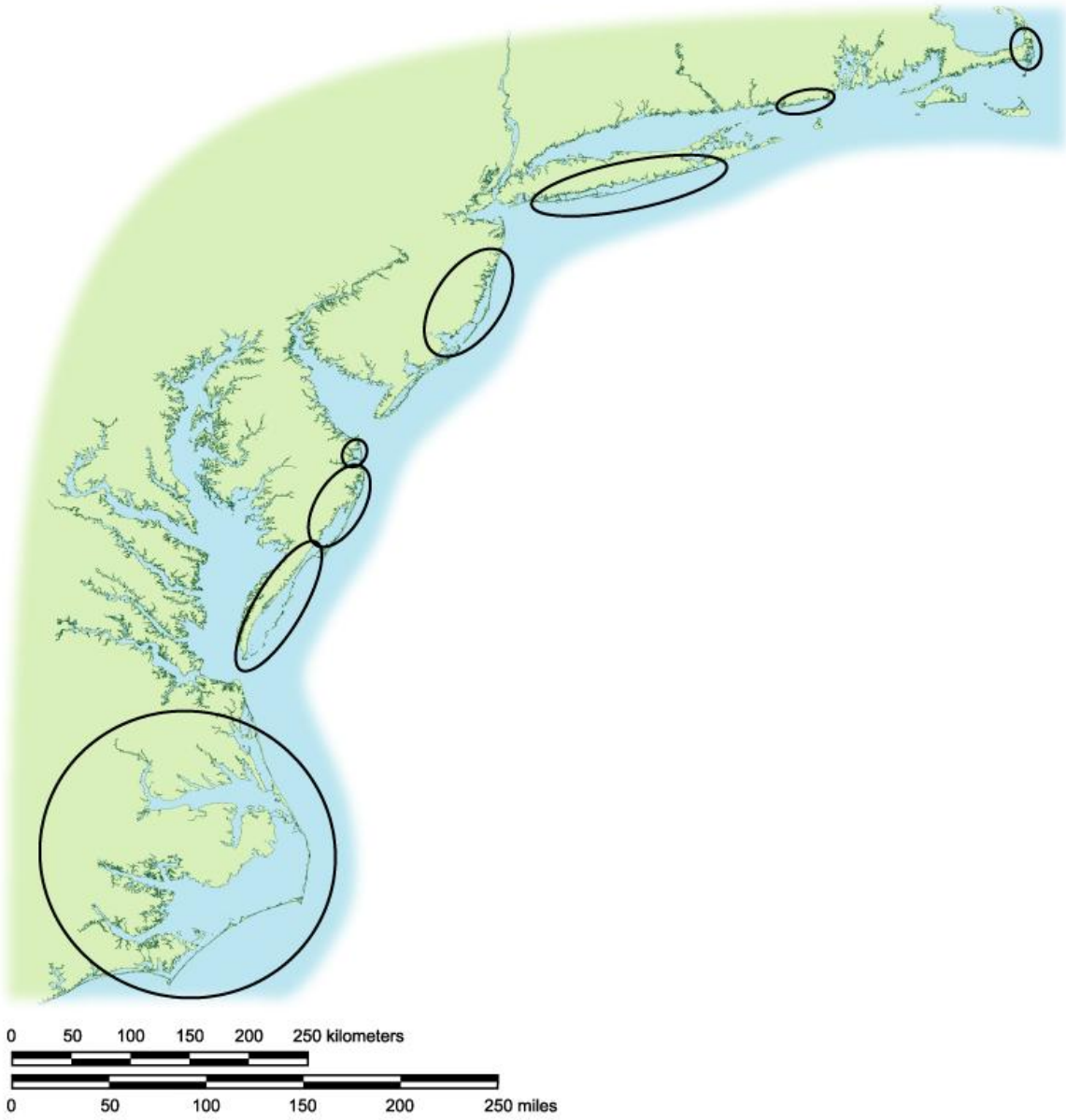
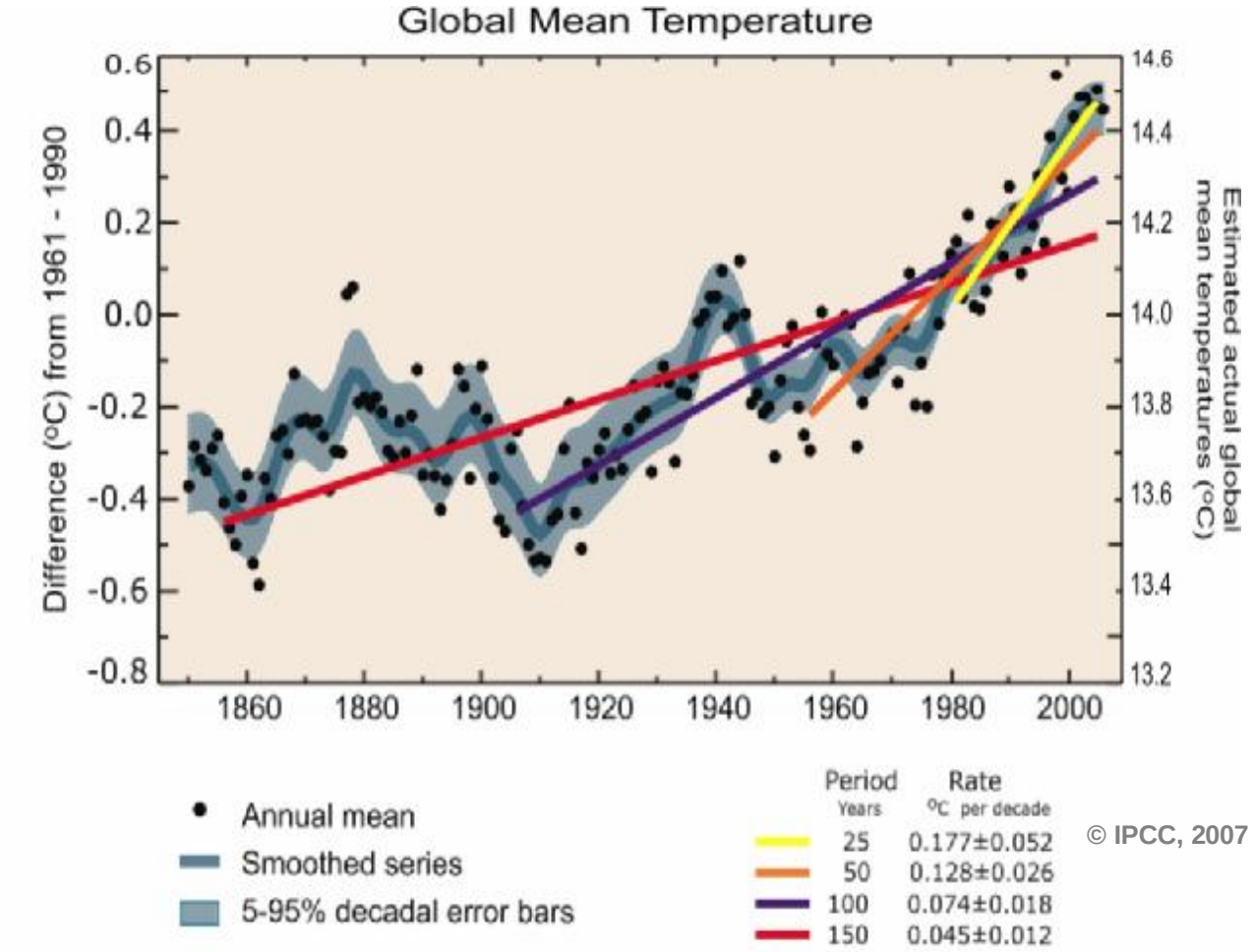
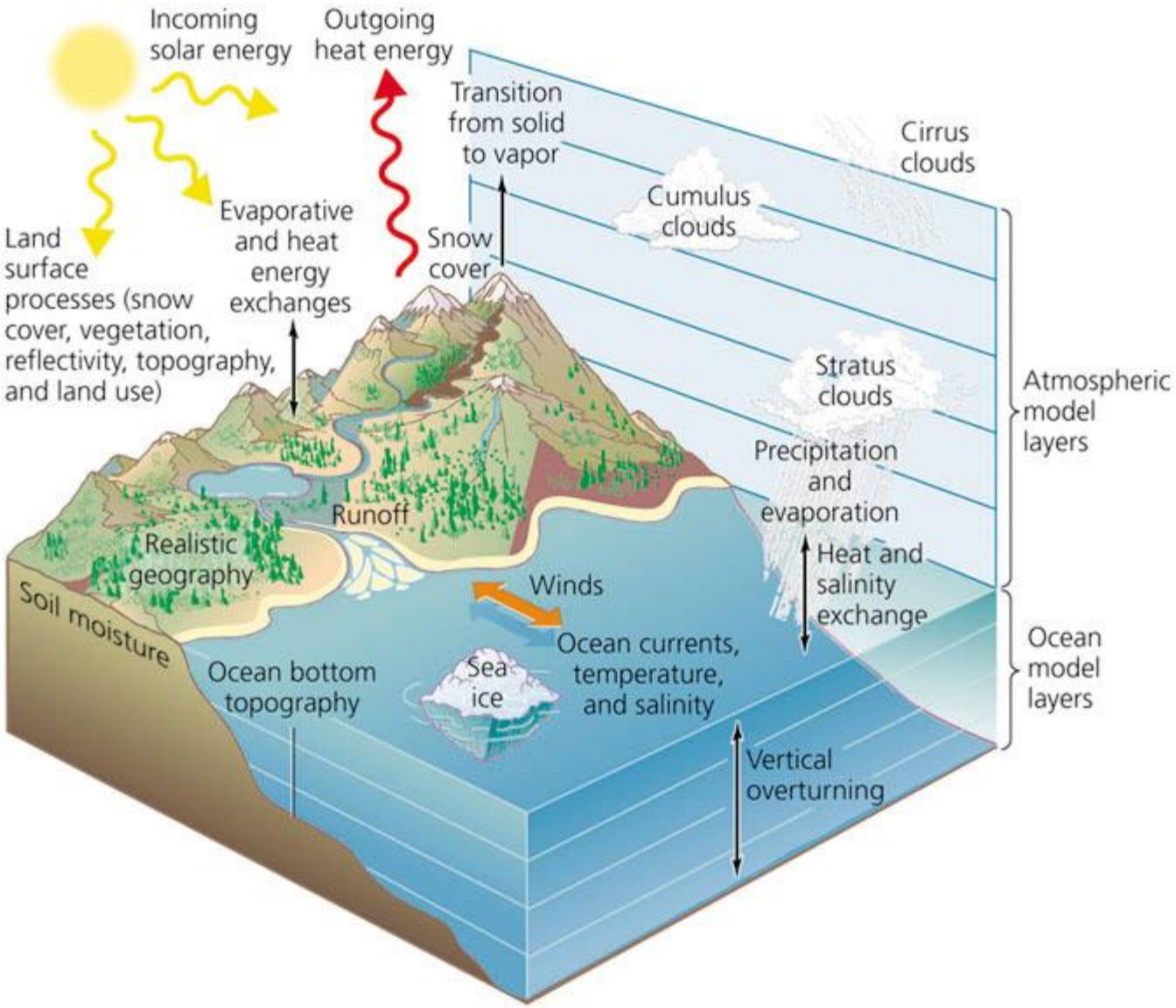
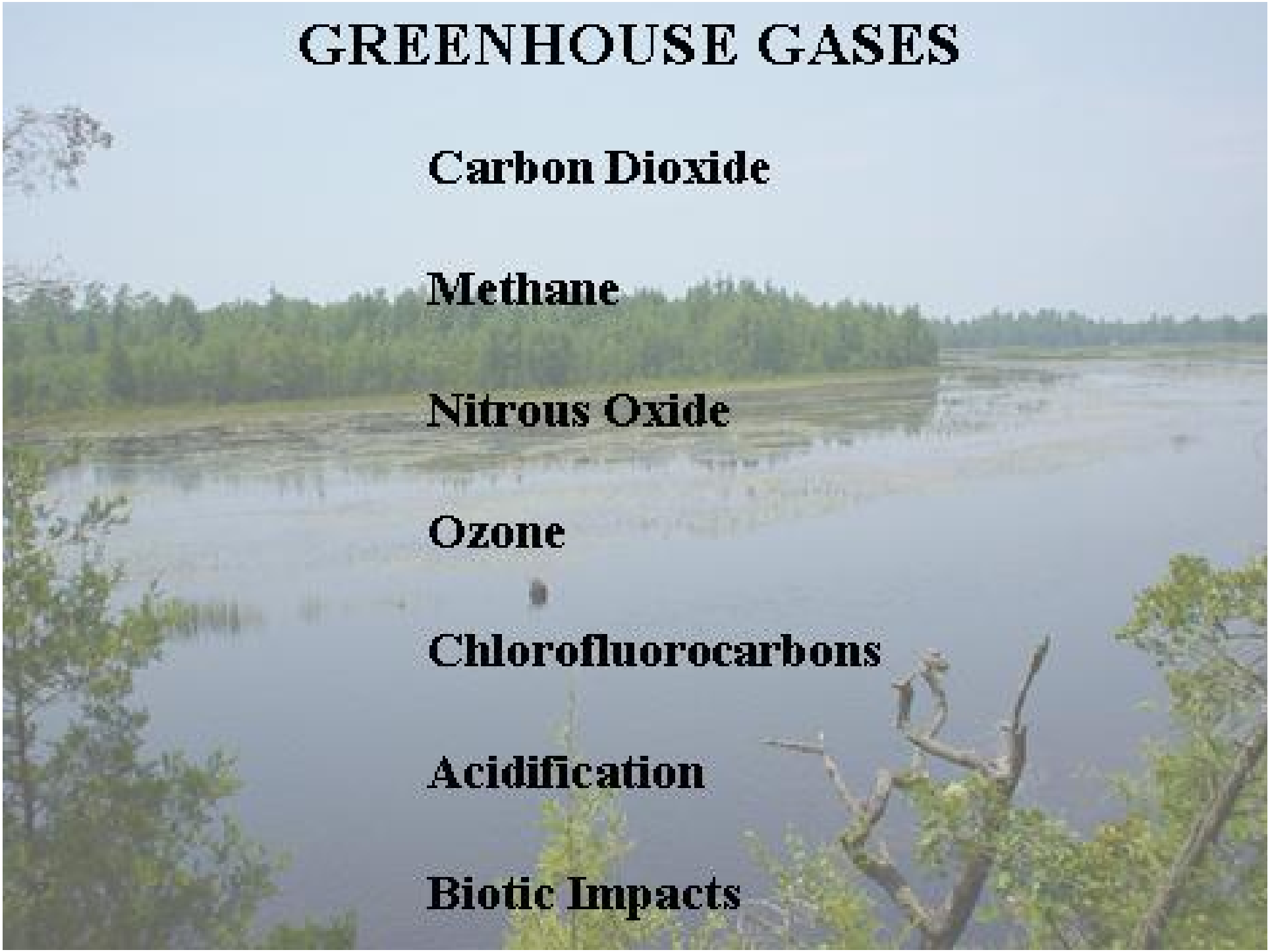

0 50 100 150 200 250 kilometers
0 50 100 150 200 250 miles

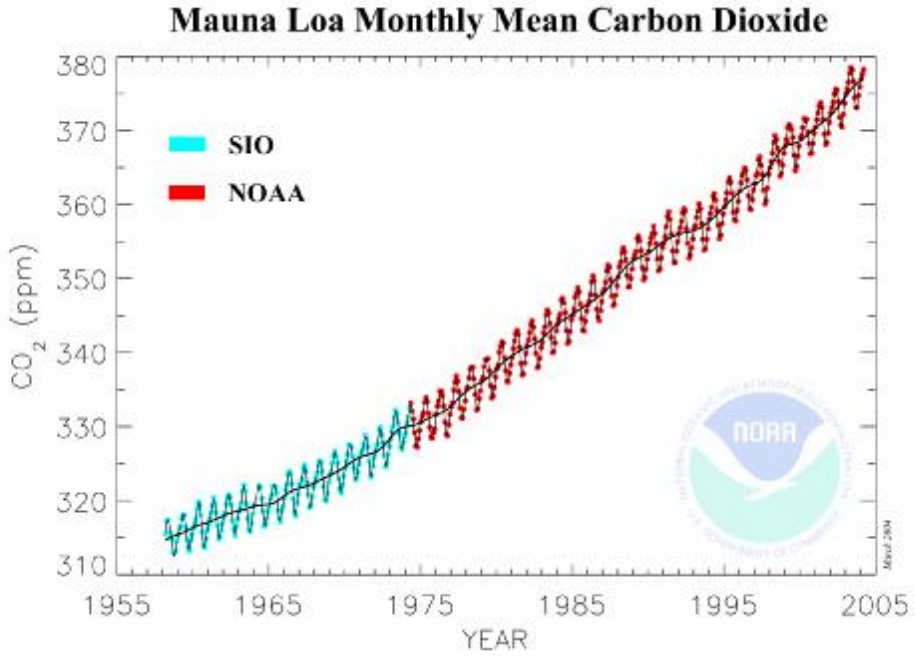
Observed Change - Temperature

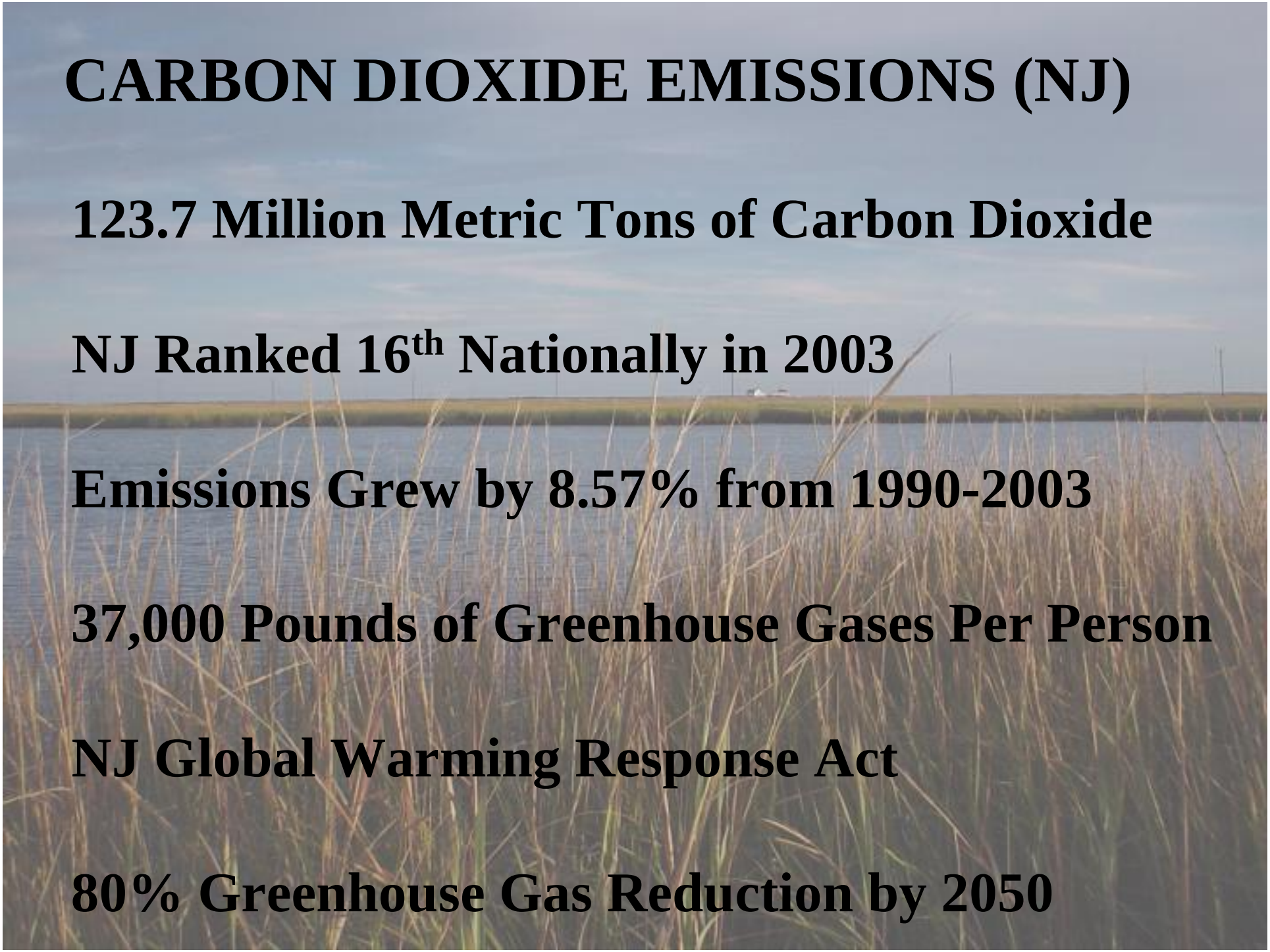
- **Global Average Temp Increased 0.74°C in the Past 100 yrs and 0.65°C in the past 50 yrs**
- **75-85% = Fossil-Fuel Burning; 15-25% = Deforestation**






GREENHOUSE GASES
Carbon Dioxide
Methane
Nitrous Oxide
Ozone
Chlorofluorocarbons
Acidification
Biotic Impacts


Mauna Loa Monthly Mean Carbon Dioxide
SIO
NOAA
CO_2 (ppm)
380
370
360
350
340
330
320
310
1955
1965
1975
1985
1995
2005
YEAR
NOAA



CARBON DIOXIDE EMISSIONS (NJ)

123.7 Million Metric Tons of Carbon Dioxide

NJ Ranked 16th Nationally in 2003

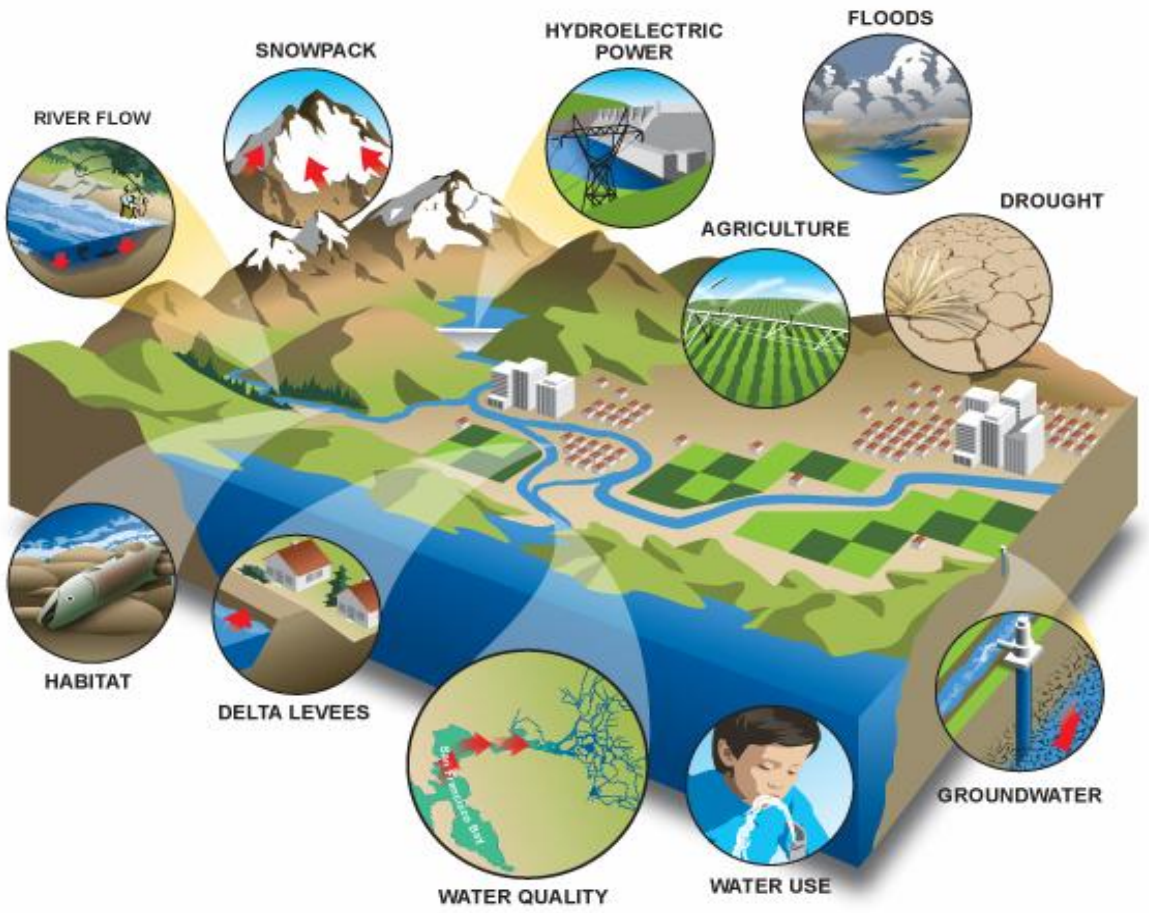
Emissions Grew by 8.57% from 1990-2003

37,000 Pounds of Greenhouse Gases Per Person

NJ Global Warming Response Act

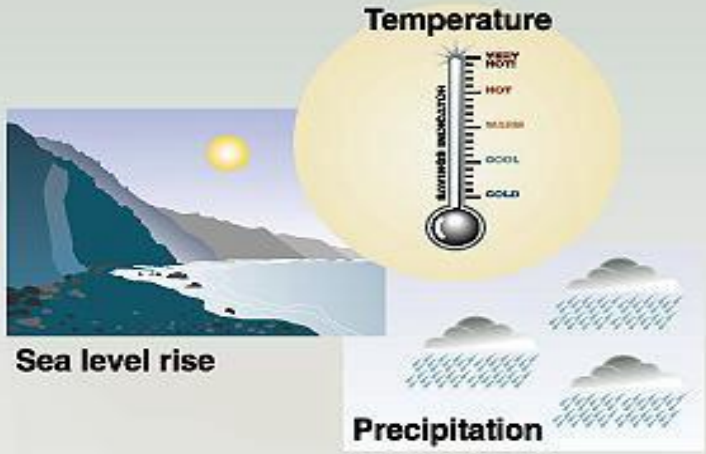
80% Greenhouse Gas Reduction by 2050

Global Warming Impacts



Source: California DWR

Potential climate changes impact



Impacts on...

Health

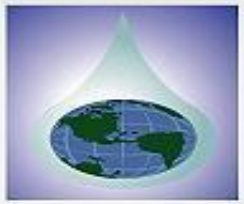
Weather-related mortality
Infectious diseases
Air-quality respiratory illnesses

Agriculture

Crop yields
Irrigation demands

Forest

Forest composition
Geographic range of forest
Forest health and productivity



Water resources

Water supply
Water quality
Competition for water

coastal areas

Erosion of beaches
Inundation of coastal lands
additional costs to protect coastal communities

Species and natural areas

Loss of habitat and species
Cryosphere: diminishing glaciers

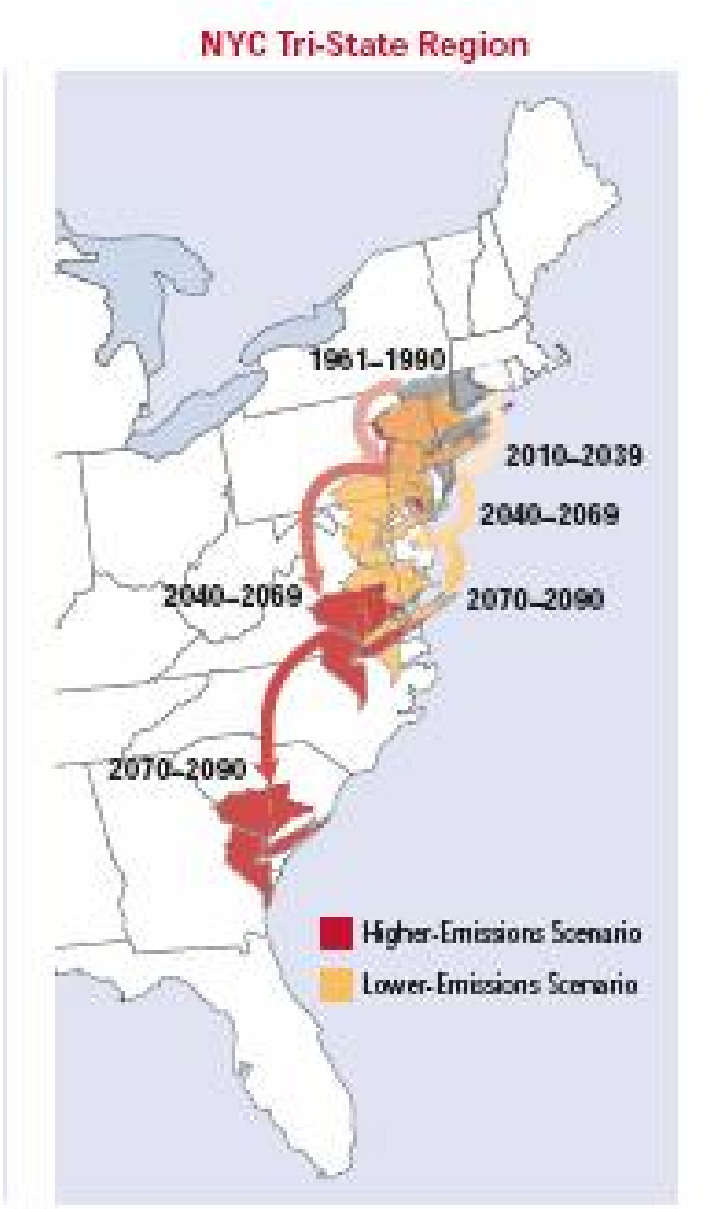
GRID Arendal UNEP

GRAPHIC DESIGN : PHILIPPE REKACEWICZ

Source: United States environmental protection agency (EPA).

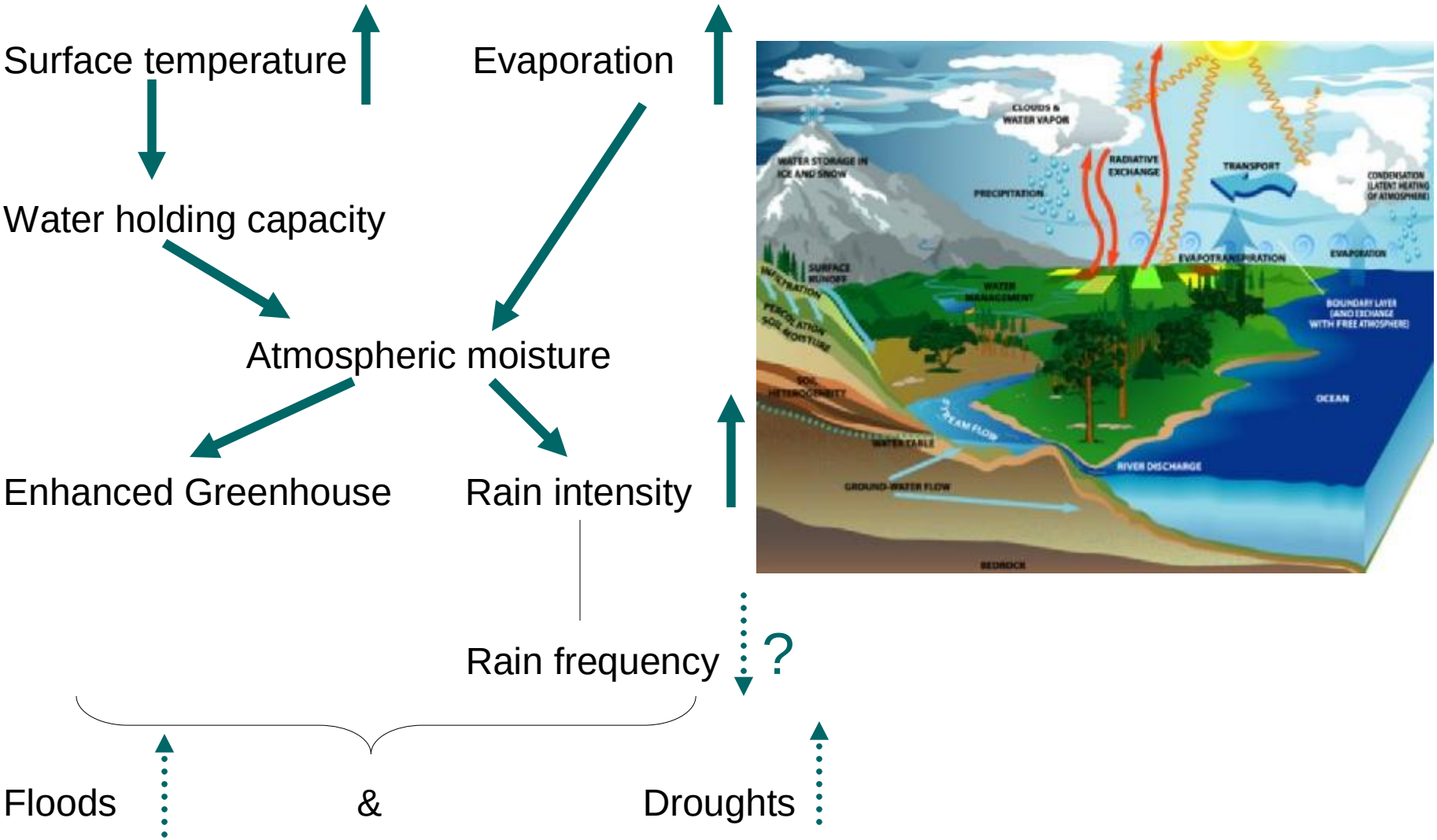
Highly Vulnerable Natural Systems

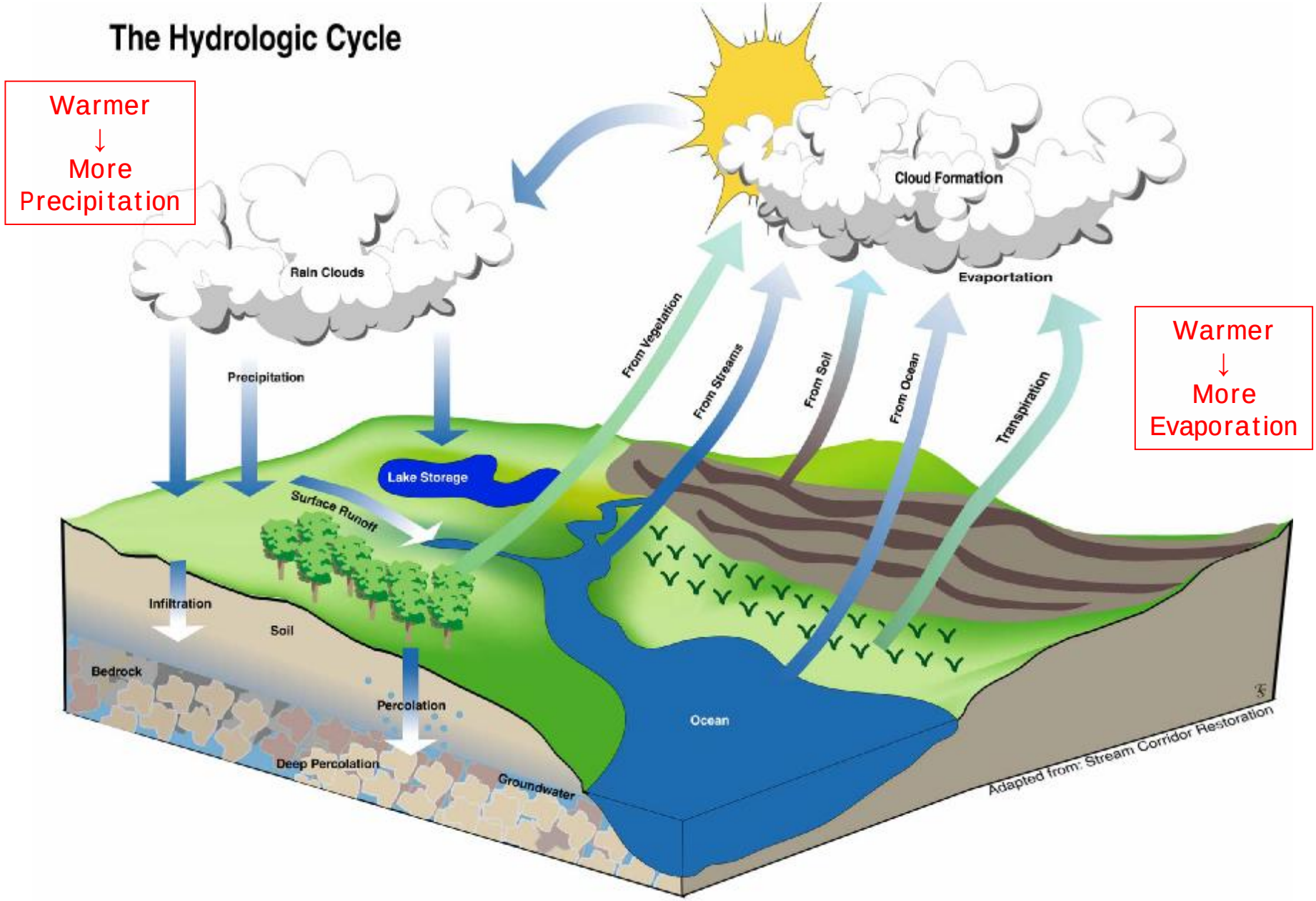
- Arid Ecosystems
- High Latitude, High Altitude Ecosystems
- Glacial Fed Regions
- Coral Reefs
- Wetlands and Freshwater Ecosystems
- Low-lying Coastal Areas
- Coastal Deltas



By 2070-2090
High CO2 Emissions è
Climate Change Comparable To Georgia and South Carolina

Warming Accelerates the Hydrologic Cycle




The Hydrologic Cycle
Warmer
↓
More
Precipitation
Cloud Formation
Rain Clouds
Evaportation
From Vegetation
From Streams
From Soil
From Ocean
Transpiration
Warmer
↓
More
Evaporation
Precipitation
Lake Storage
Surface Runoff
Infiltration
Soil
Bedrock
Percolation
Deep Percolation
Groundwater
Ocean
Adapted from: Stream Corridor Restoration

More Floods and Droughts?

Spruce Run Reservoir:
March 2002

Easton-Phillipsburg
Bridge: June 2006

Delaware River: Sept. 2004

September 2004

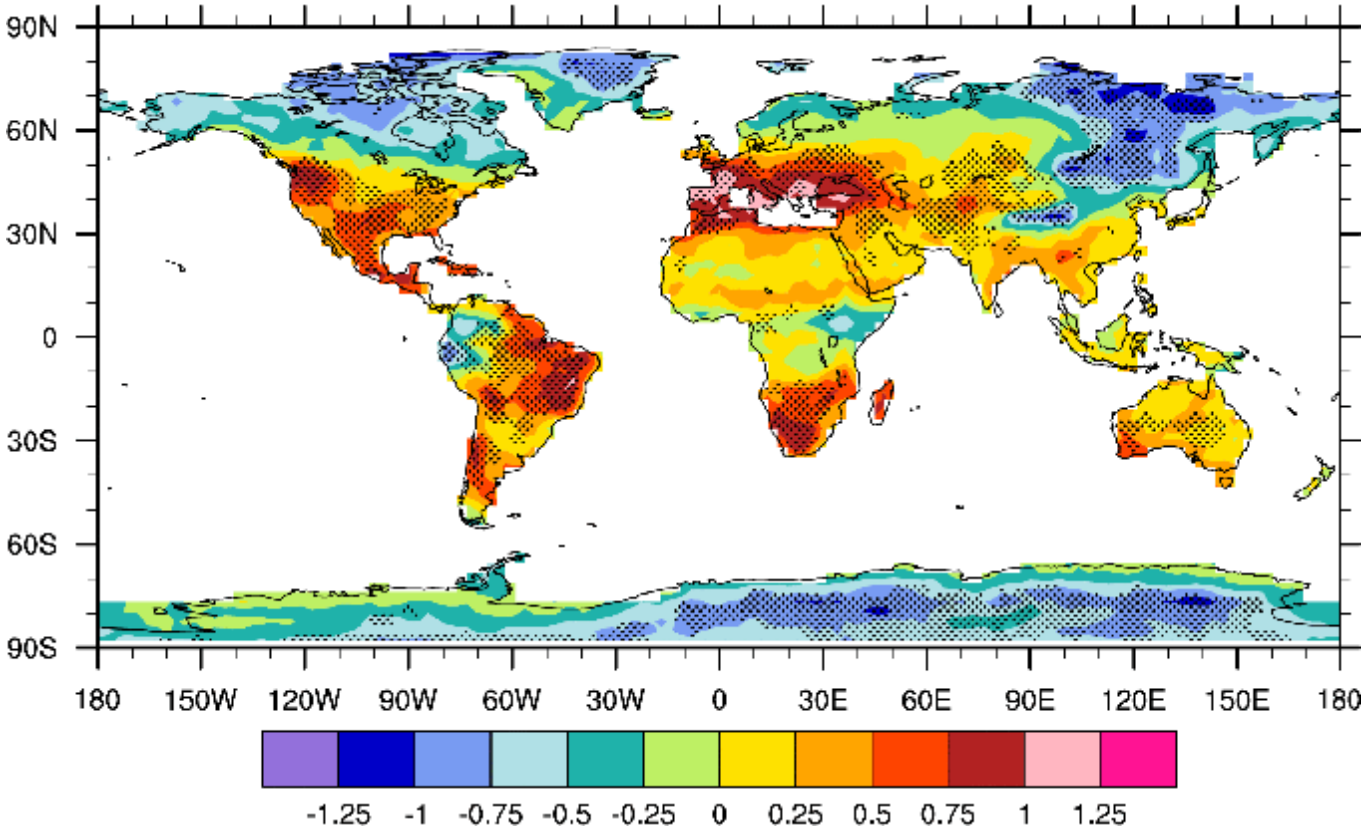
April 2005

June 2006

Three Major Floods along the Main Stem Delaware River in less than Two Years

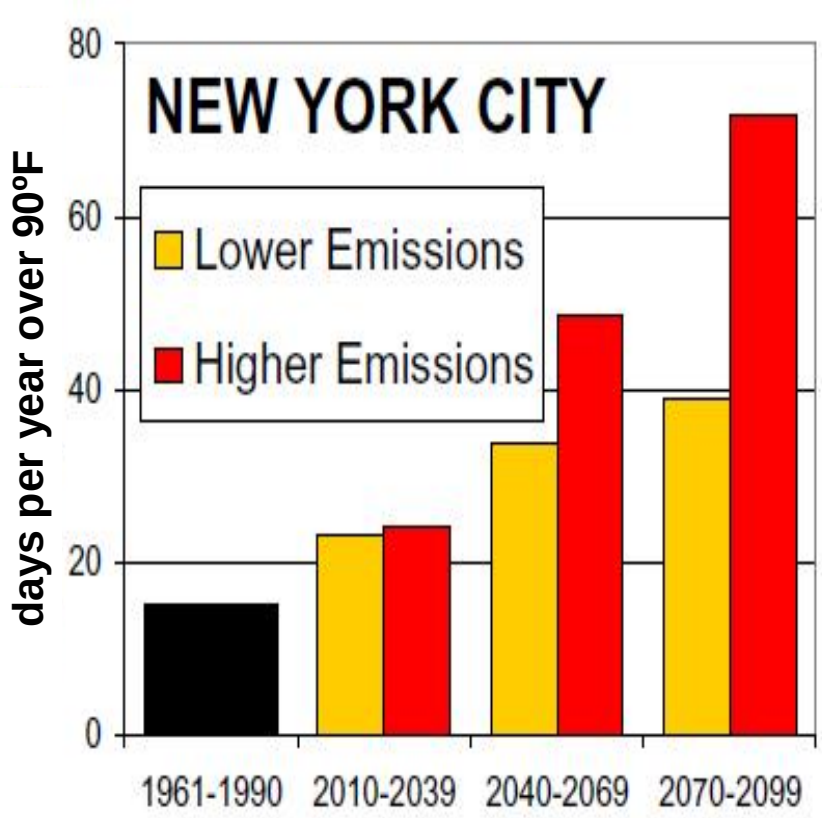
. . . And Longer Dry Spells

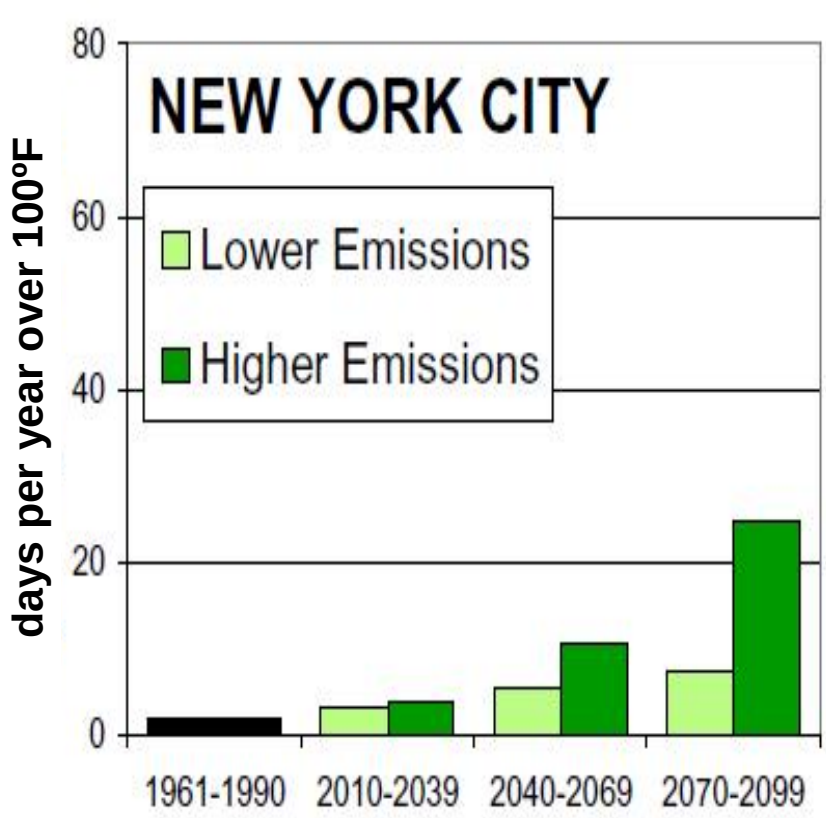
Index of change in number of consecutive dry days



Mid-range climate scenario – Nine model average (2080-2099 relative to 1980-1999). Figure courtesy of Claudia Tebaldi

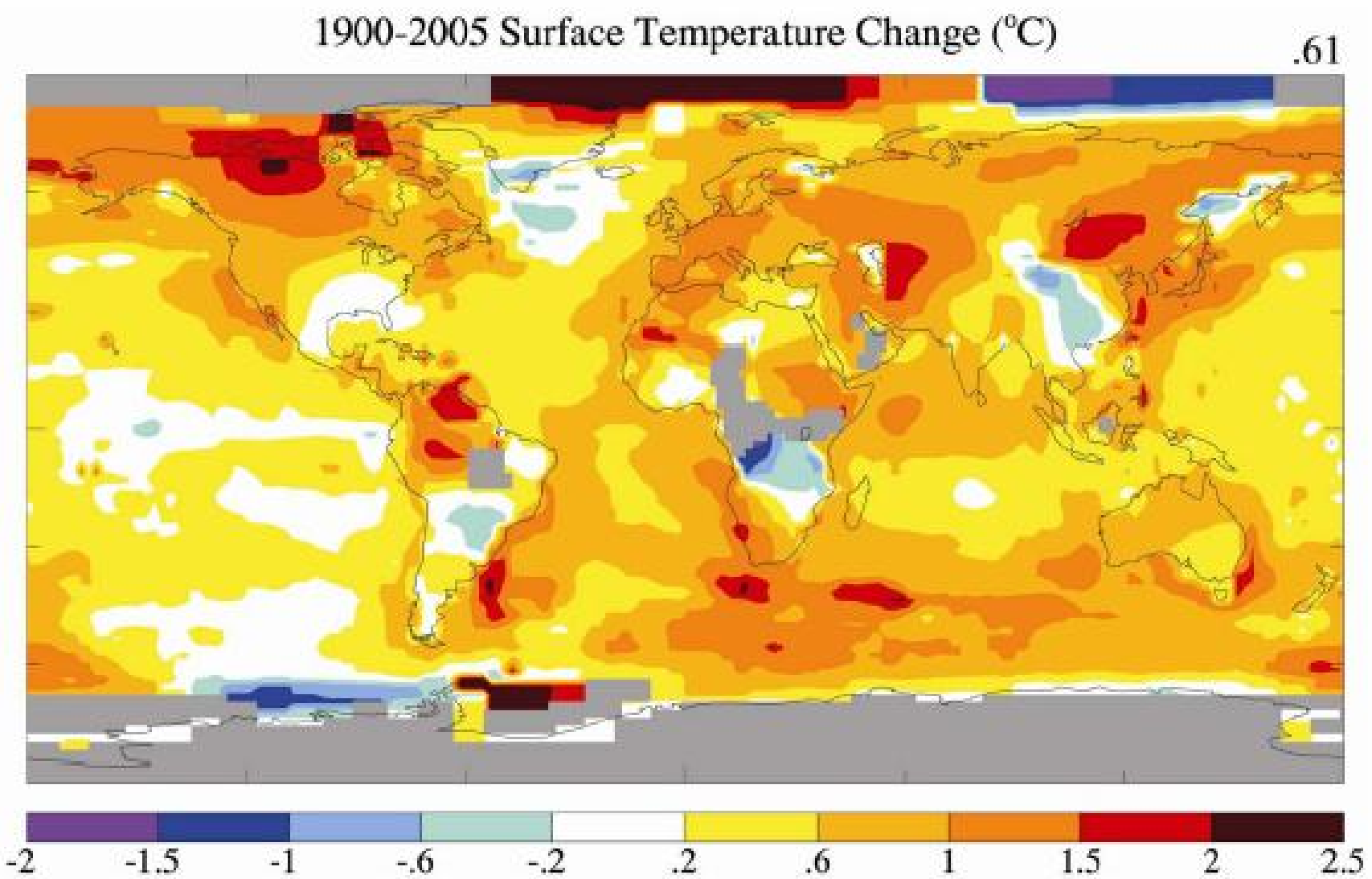
"It is *very likely* that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent."





Changes in number of days with heat waves

Source: UCS Northeast Climate Impacts Assessment

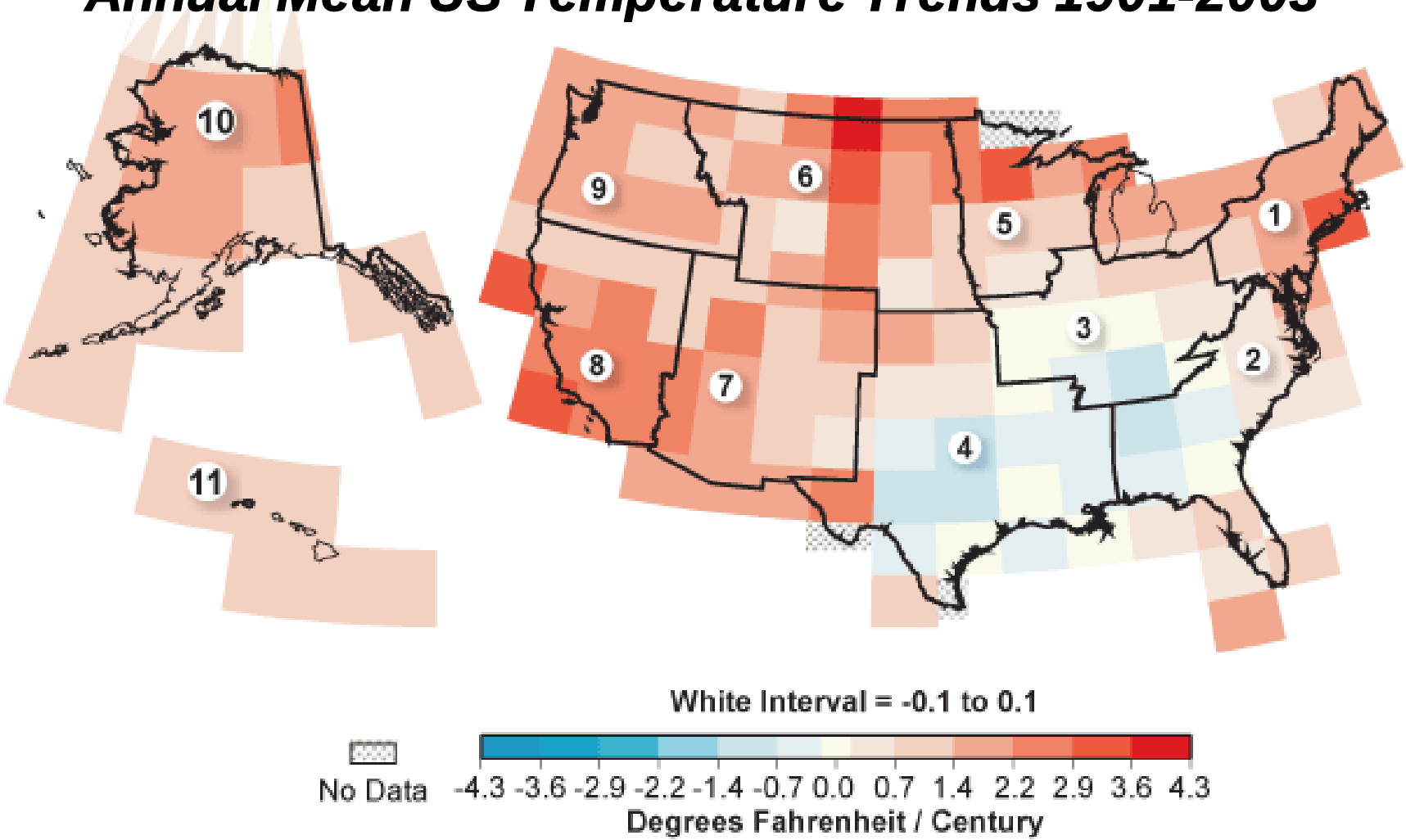


Change of surface temperature index based on local linear trends using surface air temperature over land and SST over ocean.

Sources: Hansen et al., *JGR*, **106**, 23947, 2001; Reynolds and Smith, *J. Climate*, **7**, 1994; Rayner et al., *JGR*, **108**, 2003.

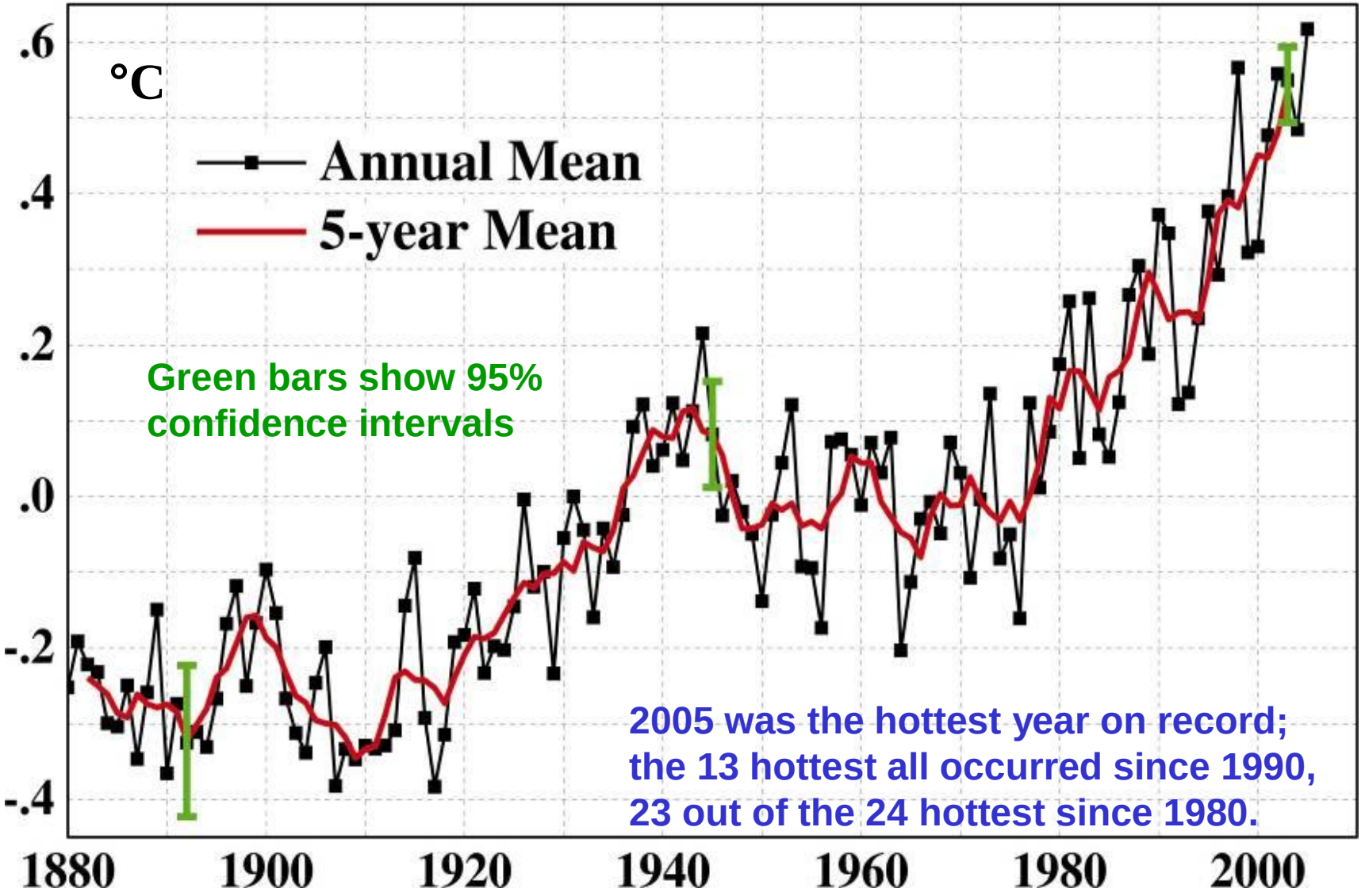
Warming Trend Observed in Most of US

Annual Mean US Temperature Trends 1901-2003



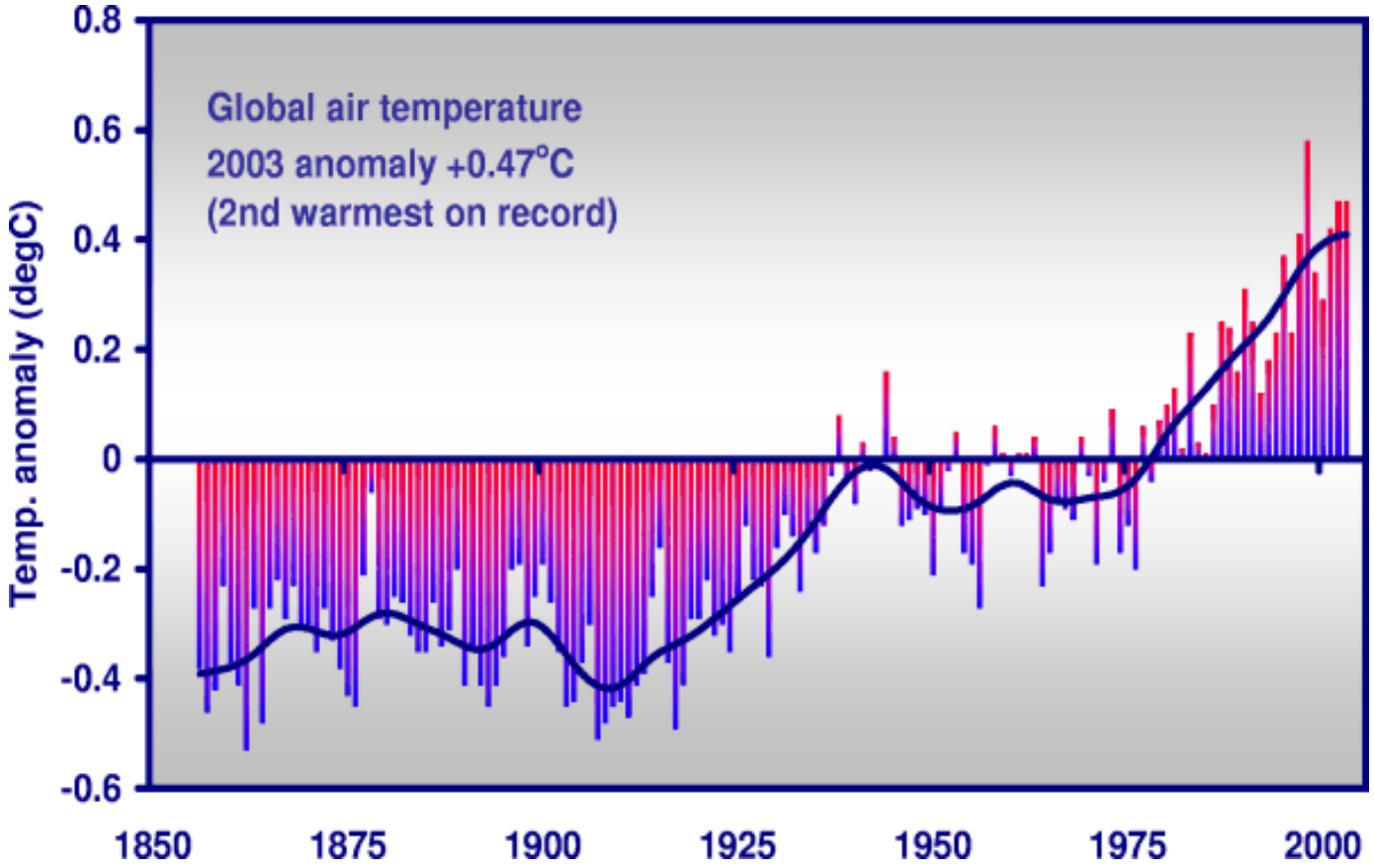
Data from NOAA/NCDC; See: http://www.epa.gov/climatechange/science/recenttc.html

Global Surface Temperature 1880-2005



J. Hansen et al., *PNAS 103*: 14288-293 (26 Sept 2006)

Global Air Temperature



Key Findings – IPCC 2007 Report
Impacts, Vulnerability and Adaptation

Chapter 1 – Observed Change in Physical and Biological Systems

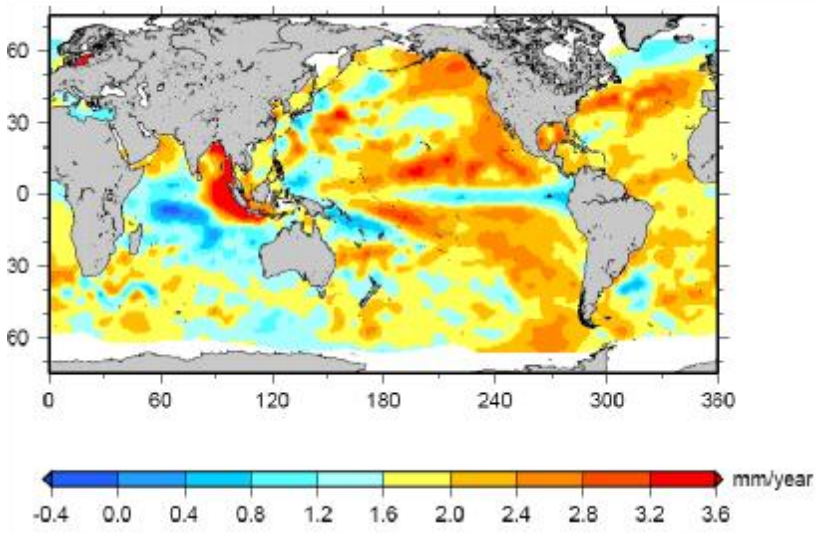
Physical and biological systems on all continents and in some oceans are already being affected by recent climate changes, particularly regional temperature increases (very high confidence).

Global-scale assessment of observed changes shows that it is likely that anthropogenic warming over the last three decades has had a discernible influence on many physical and biological systems (high confidence). (Source: Virginia Burkett, USGS).

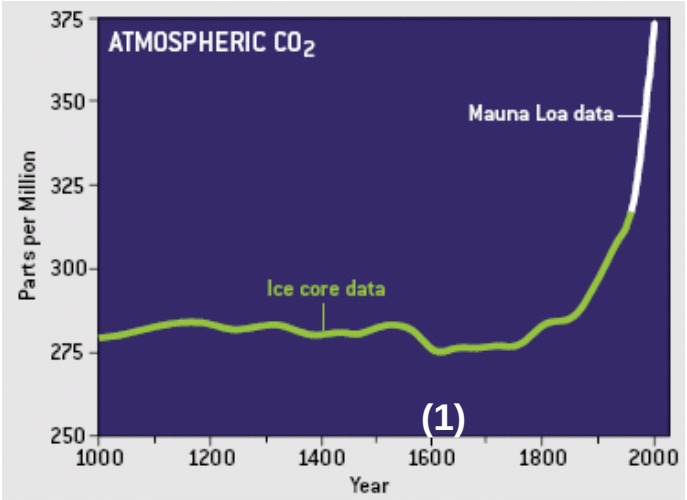
Observed Change - Oceans

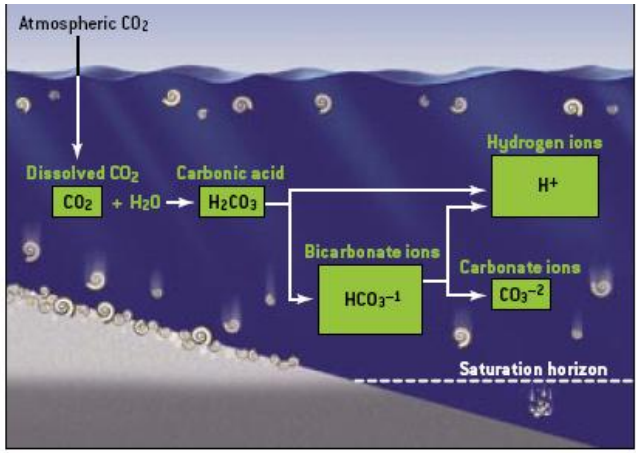
- Ocean Temperature Increase to 3000-m Depth
- Increase in North Atlantic Hurricane Activity
- Global Sea Level Rise
  - 1.7 mm/yr during 20th century
  - 3.1 mm/yr during 1993-2003

Geographic Variability in the Rate of Sea Level Rise (1955 to 2003)



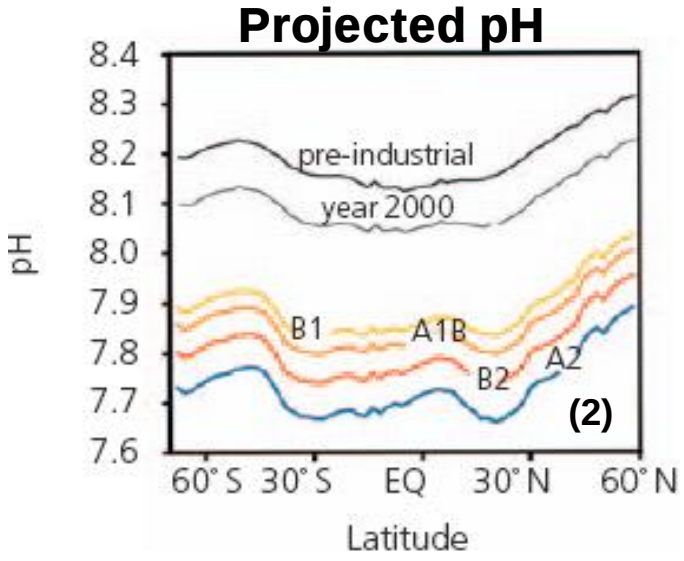
Ocean pH Is Decreasing





In past 200 years:

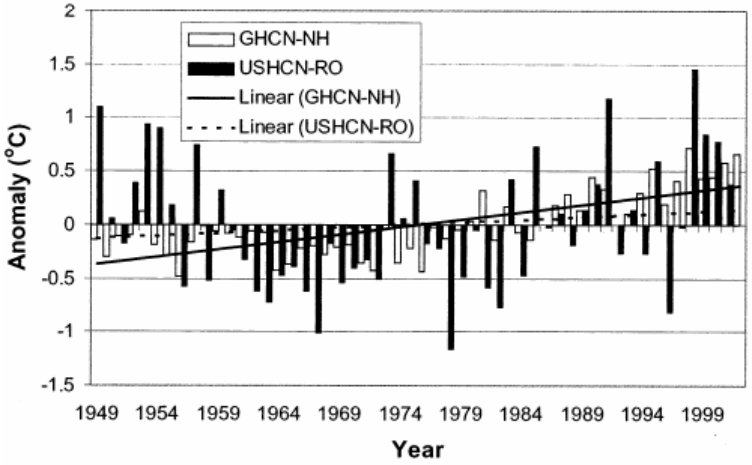
- **Oceans absorbed ½ of CO_2 emissions**
- **Ocean pH has decreased by 0.1**



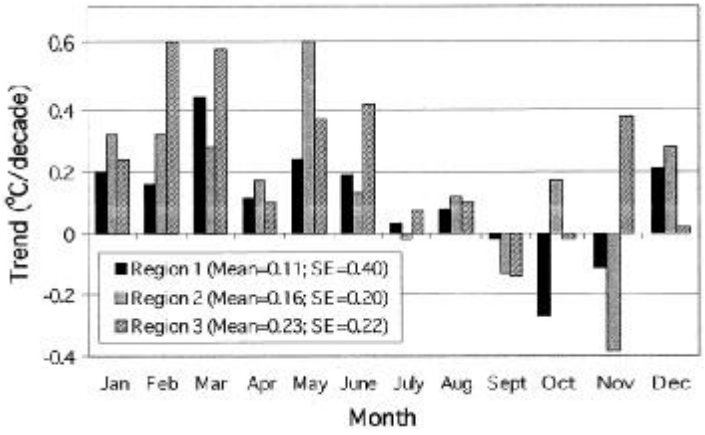
Sources: (1) Doney 2006, Sci. Amer.; (2) Royal Society 2005; (3) Kleypas et al. 2006, NSF/NOAA/USGS

Estuaries Are Warming

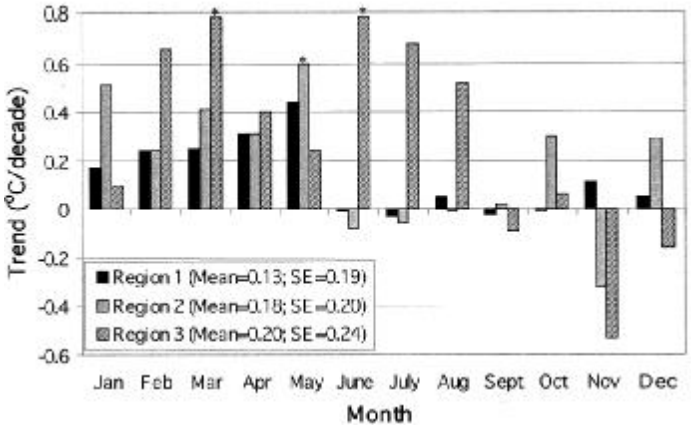
Chesapeake Bay warmed 0.8–1.1 °C (1949-2002)



Surface temperature trends



Sub-surface temperature trends



Preston 2004 Env. Mgt.

Climate Change and Chesapeake Bay

SL rise	**Current rate of SL rise (mouth of bay) is 4 mm/yr (1.3'/century) – about twice the global rate. Historic rates were 0.5 mm/yr from 1000-1850 AD, to more than 3.2 mm/yr during 20th century. Decadal rate in 1990' was 1.3 cm/yr. Subsidence rates can be on the order of 4 mm/yr.**
Temperature	**Past 100 yrs the mean temp in mid-Atlantic region has risen by 0.6 C. Today's models predict 1.2 C warmer by 2030 and 1.8-4.8 C by end of 21st century.**
Precipitation	**Past 100 yrs precipitation has increased 10%. Mean annual precipitation will increase 1-4 cm/yr (7-24% increase over current rate). Seasonal patterns of precipitation could change (wetter winters, drier summers).**
Streamflow	**Potential increase in spring streamflow (greater estuary stratification) and reduced flows in summer (salinity intrusion impacts).**
Storms	**More frequent and damaging storms. More intense precipitation.**

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VIRGINIA INSTITUTE OF MARINE SCIENCE
SCHOOL OF MARINE SCIENCE

Adaptation

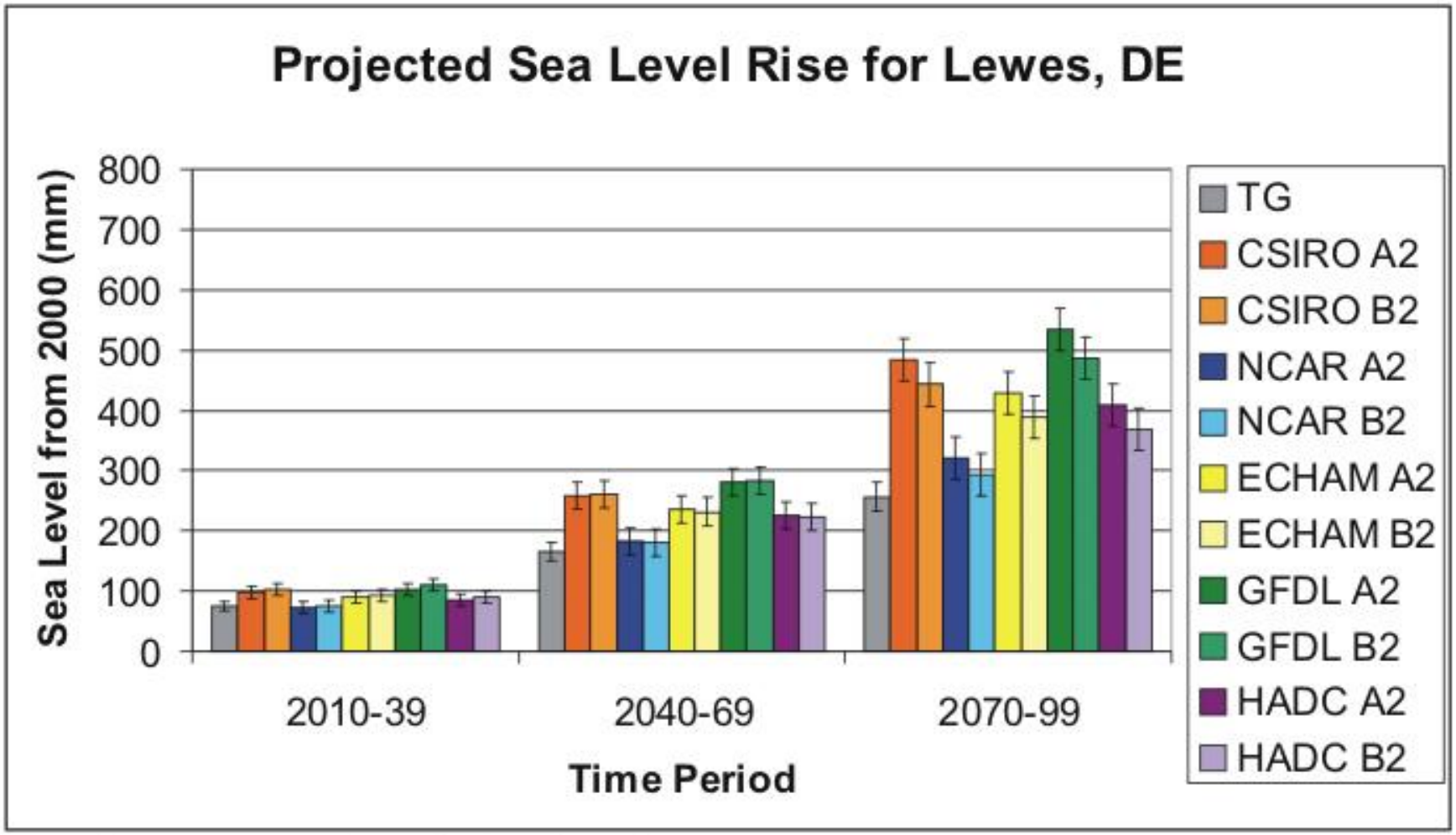
Climate Change and Habitat Restoration

~10 cm rise of sea level rise would inundate 168,000 ha (420,000 ac) of shoreline and tidal wetlands of the Chesapeake Bay ecosystem (Chesapeake Bay Commission 2007)

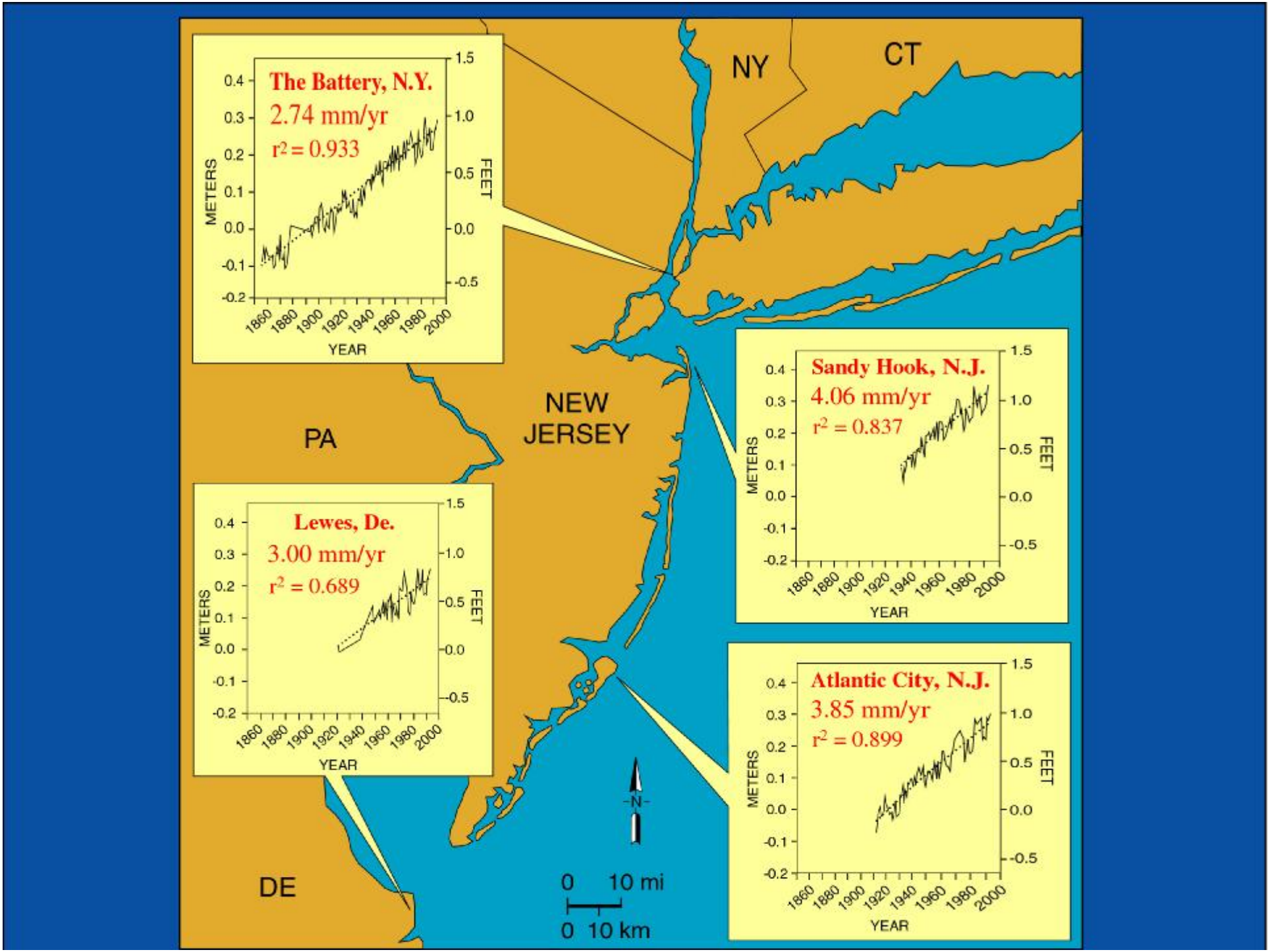
In the Chesapeake Bay region, what are the most effective places to undertake restoration?

How will the shoreline change as sea level rises and storms intensify?

Sea Level Rise - Impacts on the Delaware Estuary

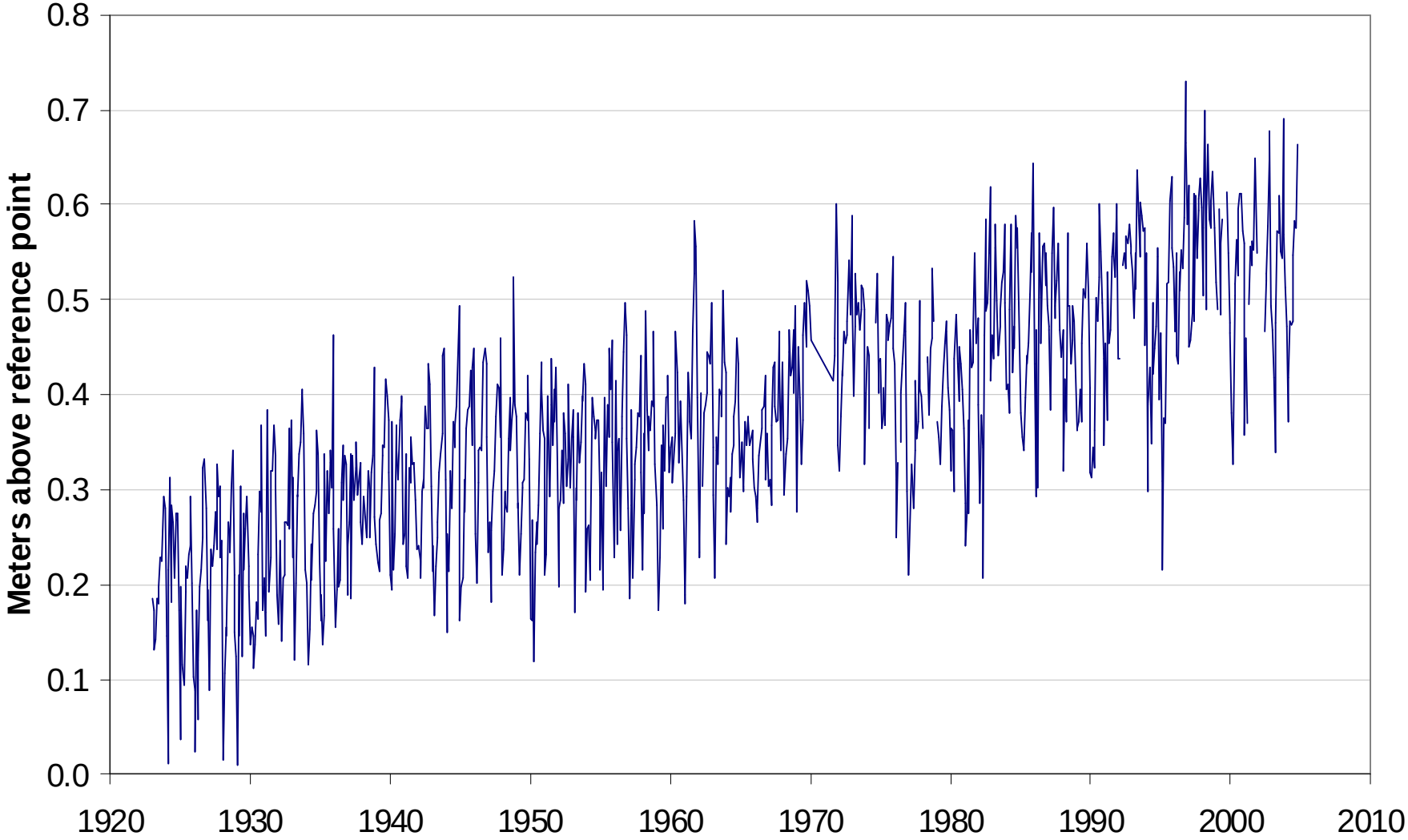


http://www.cara.psu.edu/coastal/tideproj/lewes_de.asp


NY
CT
NEW JERSEY
PA
DE
The Battery, N.Y.
2.74 mm/yr
r² = 0.933
Sandy Hook, N.J.
4.06 mm/yr
r² = 0.837
Lewes, De.
3.00 mm/yr
r² = 0.689
Atlantic City, N.J.
3.85 mm/yr
r² = 0.899
METERS
FEET
YEAR
N
0 10 mi
0 10 km

Sea Level; Atlantic City, NJ

Tide gauge data, from National Oceanic and Atmospheric Administration

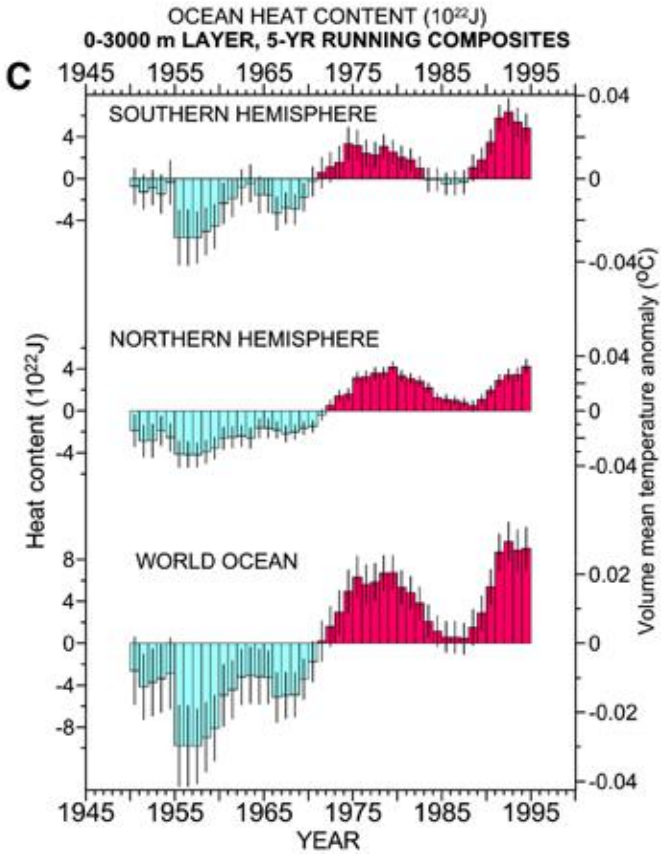


Why Is Global Sea Level Rising?

- Thermal expansion

  Warmer water is less dense than colder water.

- Melting of glaciers and ice caps



Shrinking Glaciers

Near-term – increased summer streamflow – Long-term reductions.

Alaska's Toboggan Glacier is one of thousands in the state that have receded dramatically in the last century, as shown in this pair of photos from 1909 (top) and 2000 (bottom).

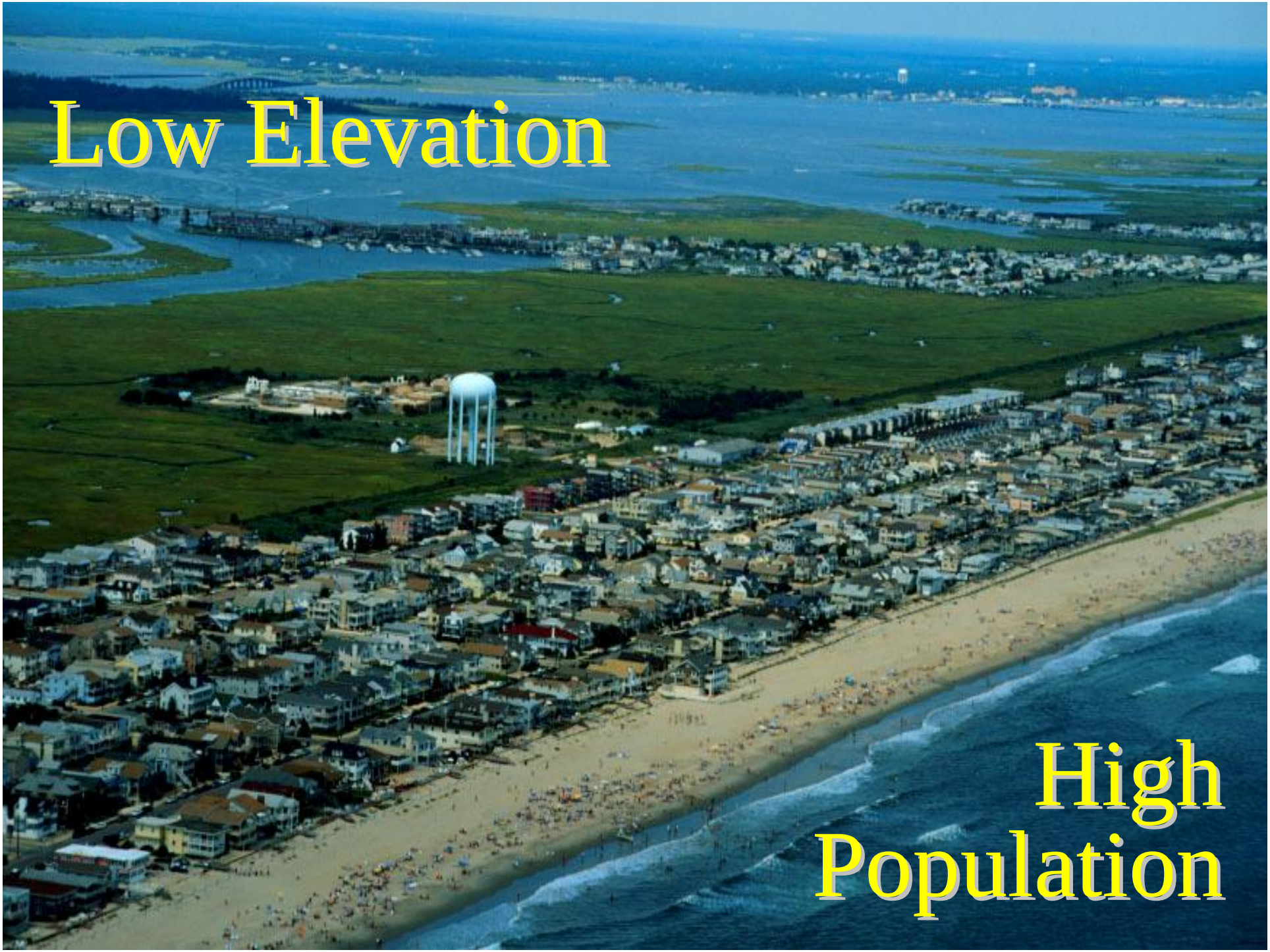
CREDIT: BRUCE MOLNIA/USGS

LOCAL/REGIONAL FACTORS

SUBSIDENCE
ISOSTATIC ADJUSMENT

- **Modified Shoreline Habitat**
- **Degraded Wetland**
- **Accelerated Fringe Erosion**
- **Open Water Habitat Expansion**

Building Codes


Low Elevation
High Population

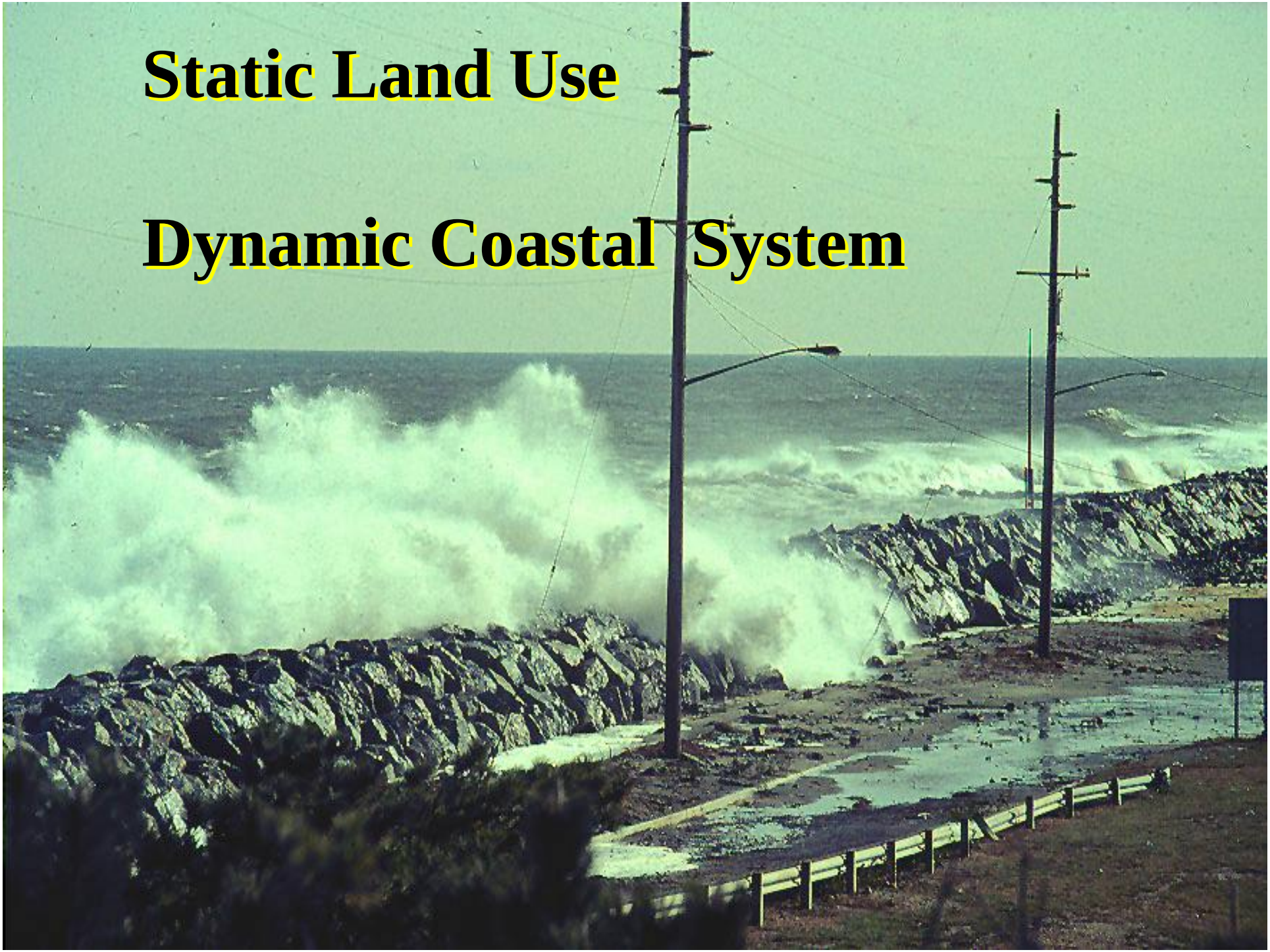
Central Issues

-overdevelopment

-beach erosion

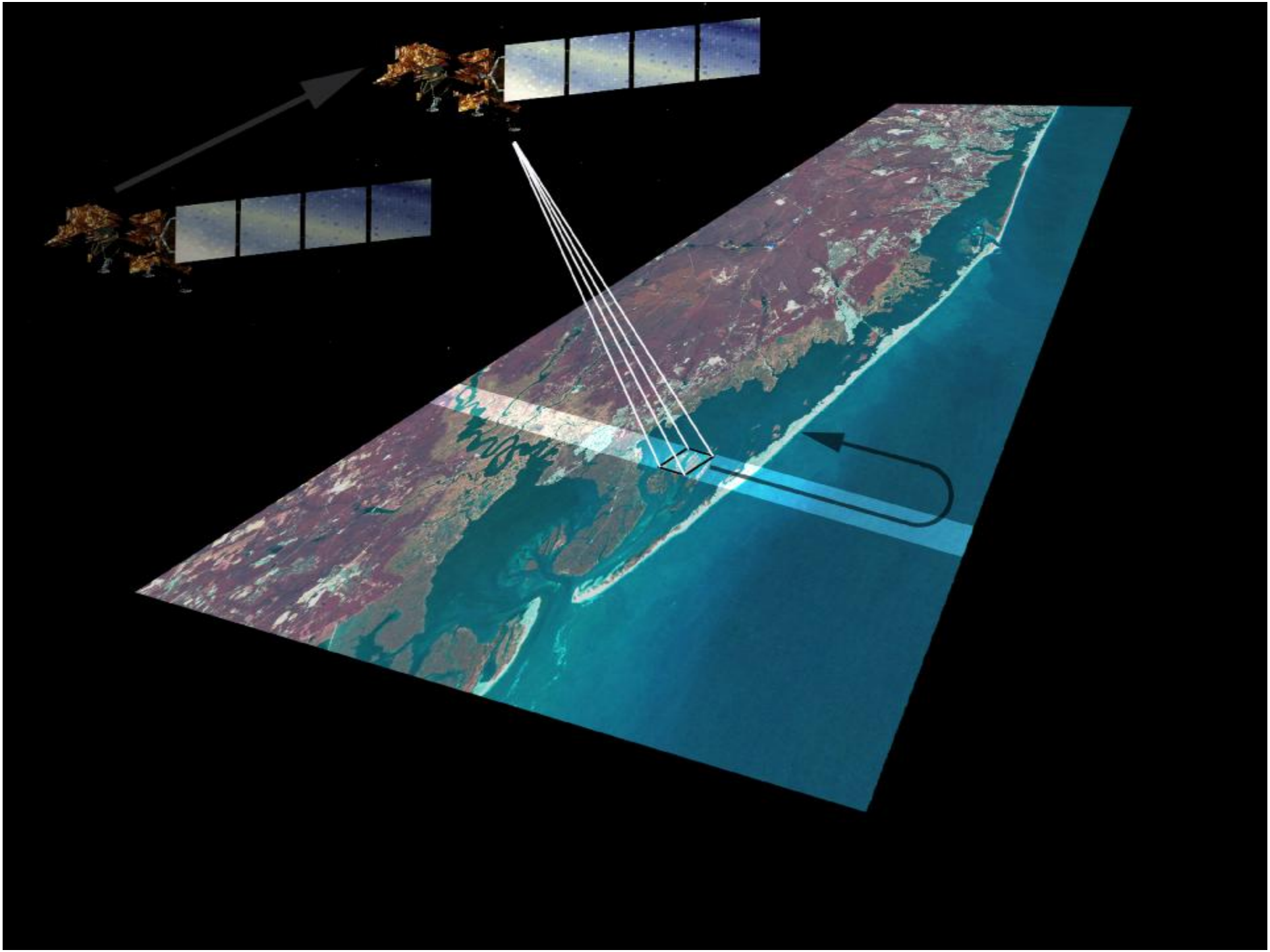
-environmental quality

-shore stabilization

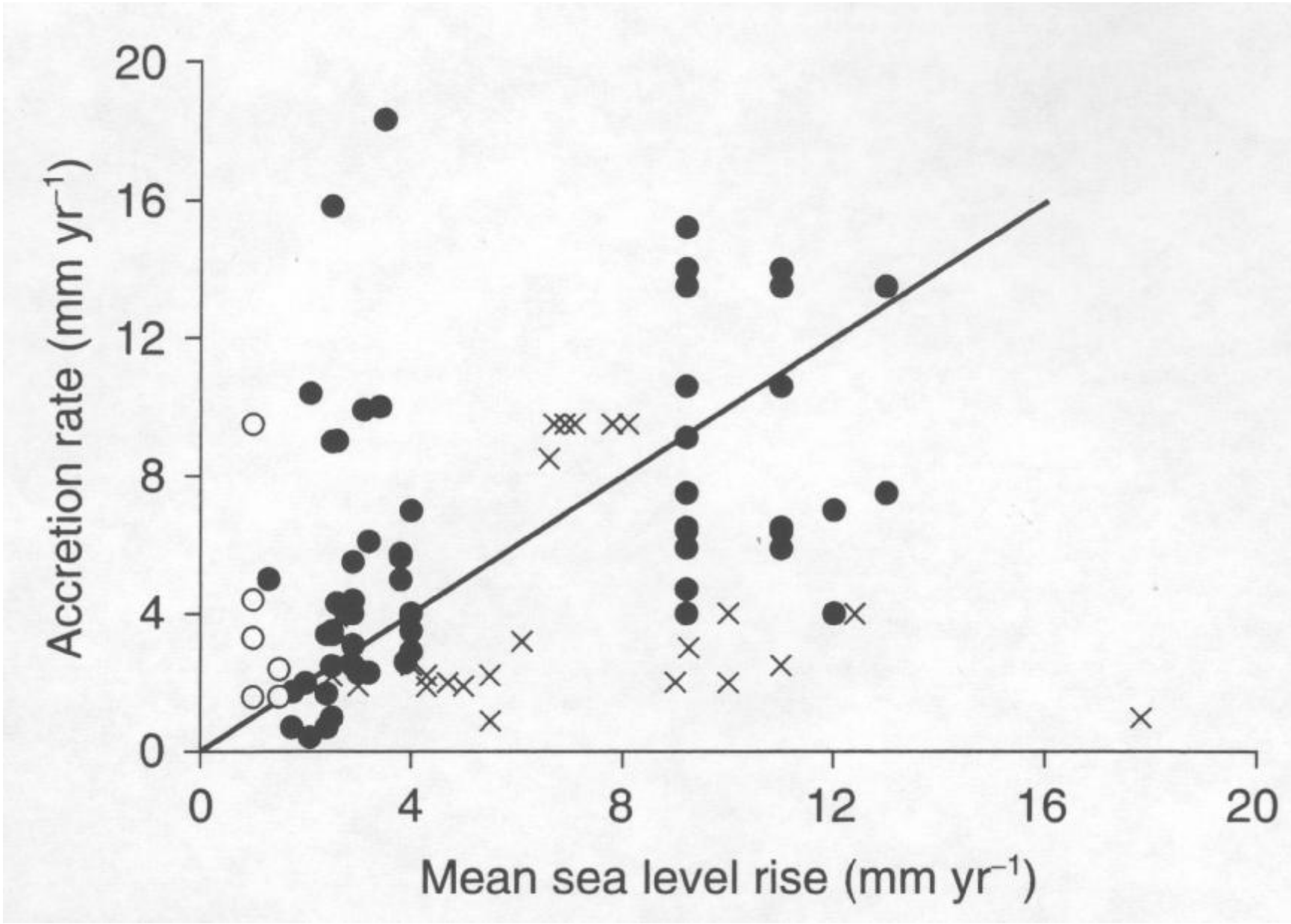

Static Land Use
Dynamic Coastal System

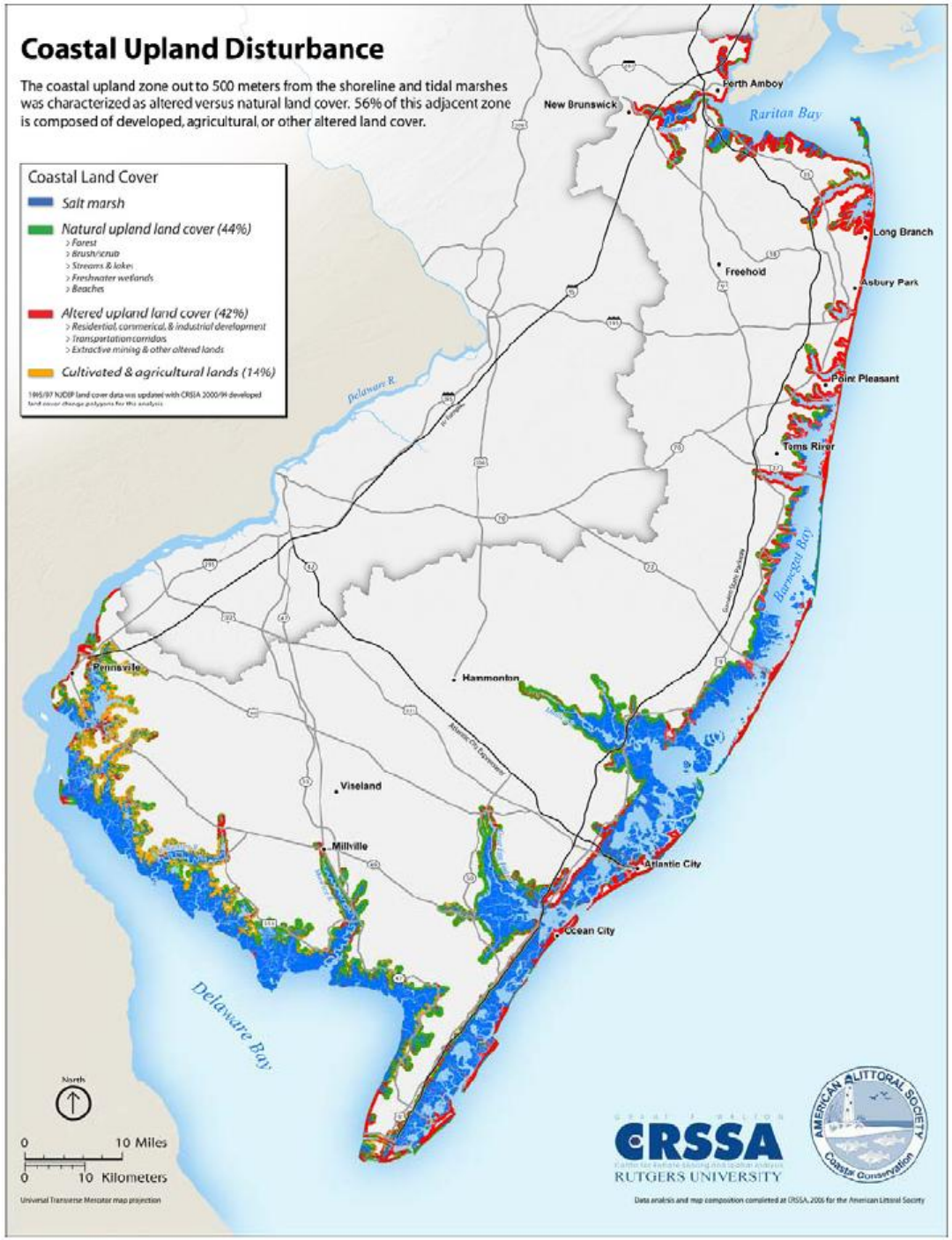
Beach Fill

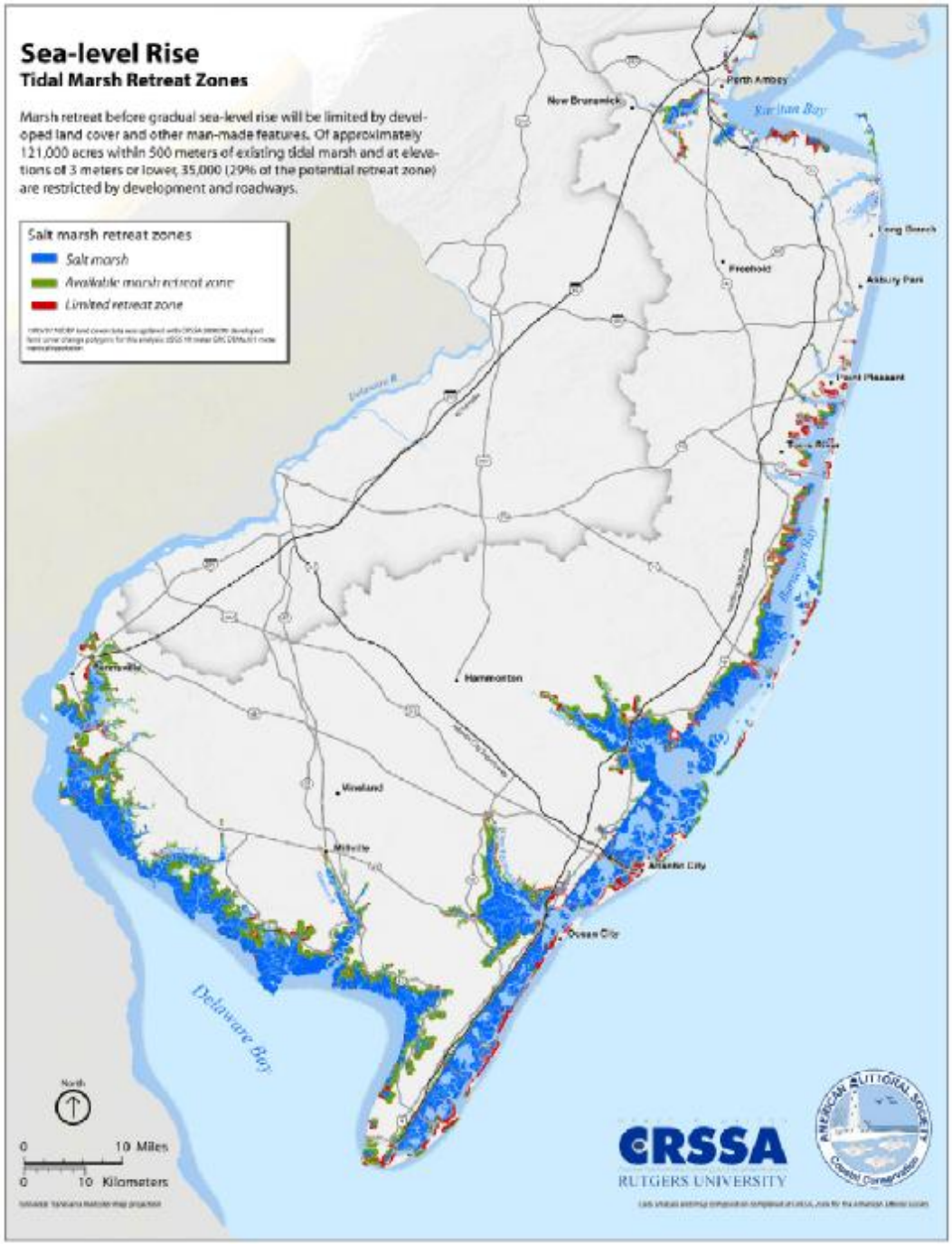
Improve Buffer



Bayside Vulnerability

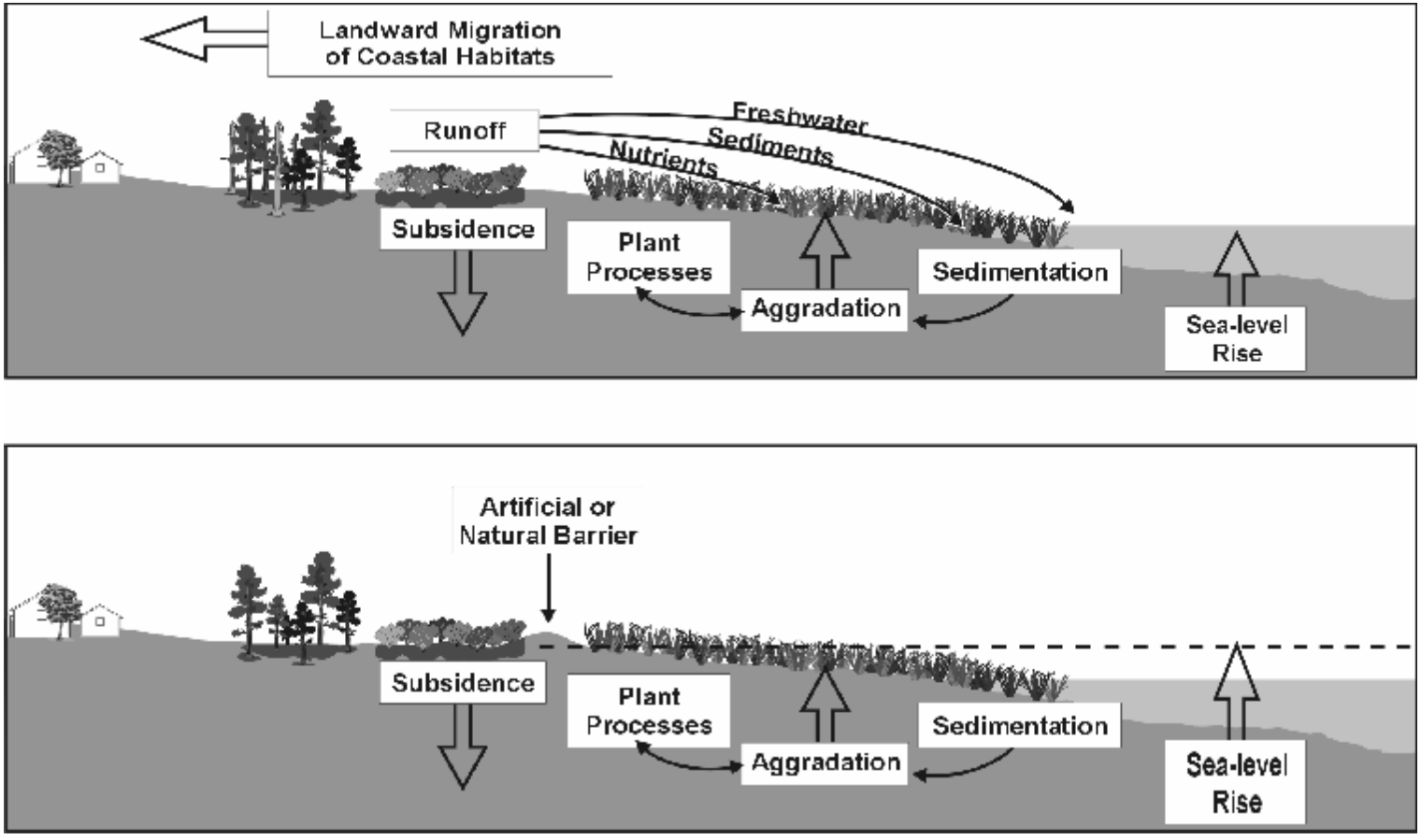

Accretion rate (mm yr^{-1})
Mean sea level rise (mm yr^{-1})
0
4
8
12
16
20


Coastal Upland Disturbance
The coastal upland zone out to 500 meters from the shoreline and tidal marshes was characterized as altered versus natural land cover. 56% of this adjacent zone is composed of developed, agricultural, or other altered land cover.
Coastal Land Cover
Salt marsh
Natural upland land cover (44%)
> Forest
> Brush/scrub
> Streams & lakes
> Freshwater wetlands
> Beaches
Altered upland land cover (42%)
> Residential, commerical, & industrial development
> Transportation corridors
> Extractive mining & other altered lands
Cultivated & agricultural lands (14%)
1995/97 NJDEP land cover data was updated with CRSSA 2000/04 developed land cover change polygons for this analysis
Perth Amboy
New Brunswick
Raritan Bay
Long Branch
Freehold
Asbury Park
Point Pleasant
Toms River
Barnegat Bay
Delaware R.
Pennsville
Hammonton
Viselend
Millville
Atlantic City
Ocean City
Delaware Bay
North
0 10 Miles
0 10 Kilometers
Universal Transverse Mercator map projection
CRSSA
RUTGERS UNIVERSITY
AMERICAN LITTORAL SOCIETY
Coastal Conservation
Data analysis and map composition completed at CRSSA, 2006 for the American Littoral Society


Sea-level Rise
Tidal Marsh Retreat Zones
Marsh retreat before gradual sea-level rise will be limited by developed land cover and other man-made features. Of approximately 121,000 acres within 500 meters of existing tidal marsh and at elevations of 3 meters or lower, 35,000 (29% of the potential retreat zone) are restricted by development and roadways.
Salt marsh retreat zones
Salt marsh
Available marsh retreat zone
Limited retreat zone
New Brunswick
Perth Amboy
Raritan Bay
Long Branch
Freehold
Asbury Park
Point Pleasant
Delaware R.
Barnegat Bay
Hammonton
Vineland
Millville
Atlantic City
Ocean City
Delaware Bay
North
0 10 Miles
0 10 Kilometers
CRSSA
RUTGERS UNIVERSITY
AMERICAN LITTORAL SOCIETY
Coastal Conservation

Adaptation

Remove Impediments to Upland Transgression of Coastal Wetlands (Restored and Natural)

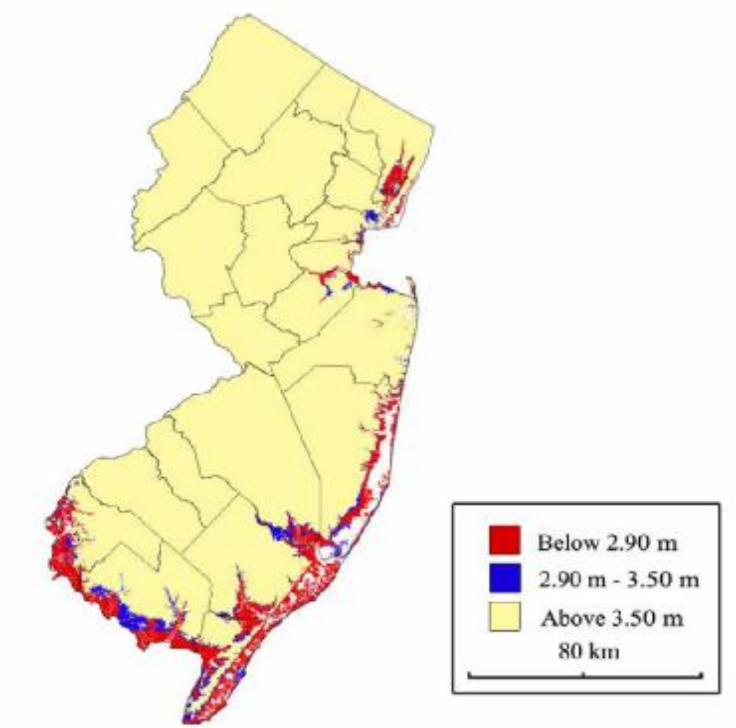


(Burkett 2001)

Impact of Sea Level Rise on New Jersey

We will lose some land.

As sea level rises so does the potential flood impact



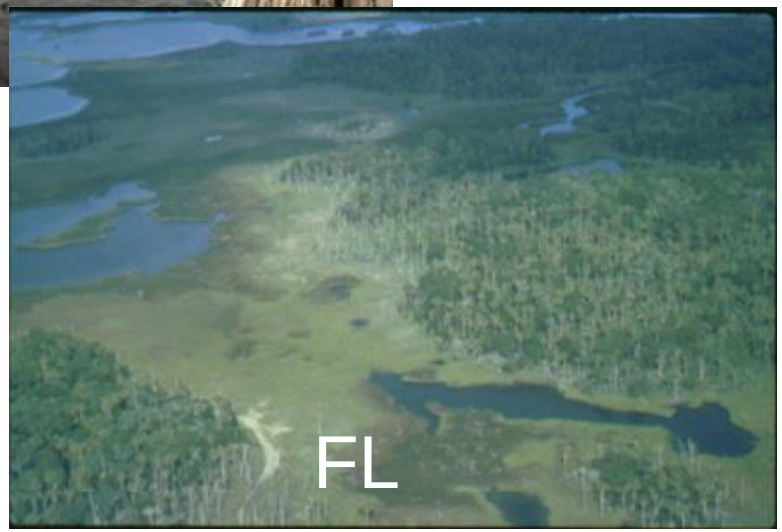
	Sea level rise (m)		
	0.61	1.22	2.90
	Area lost (km^2)		
Total	171	442	1251
Wetlands	83%	83%	72%
Forest	2%	2%	5%
Beach	3%	3%	5%
Urban	10%	10%	16%
Industrial	1%	1%	2%
Agriculture	0.2%	0.2%	4%

What will be the economic and environmental impacts? What should NJ do?

Cooper, Beevers, and Oppenheimer 2005

Other Ecological Consequences

Saltwater Inundation: Loss of Coastal Plant and Animal Communities



GLOBAL WARMING EFFECTS (2000-2100)

Surface Temperature Increase (1.4-5.8 deg. C)
Sea Level Rise (0.7-1.2 m)
Transgressing Ocean (Coastal Inundation)
Retreating Shoreline (25-30 m)
Barrier Island Overwash
Habitat Fragmentation and Destruction
Changing Aquatic Communities (<Biodiversity)
Landward Shift of Coastal Ecosystems (e.g., Wetlands)
Coastal Flooding
Saltwater Intrusion
Loss of Croplands
Displacement of Coastal Residents

SPECIES RANGE EXPANSIONS

- 36 of 39 Marine Invertebrate Species: Poleward Range Expansions

- 24 of 24 Marine Zooplankton Species: Poleward Range Expansions

  (Parmesan and Yohe. 2003. Nature 421: 37-41.)

- Southern:Northern Coastal Bird Species at Cape Cod (20th Century)

- More Southern Overwintering Species

  (Valiela and Bowen. 2003. Ambio 32: 476-480.)

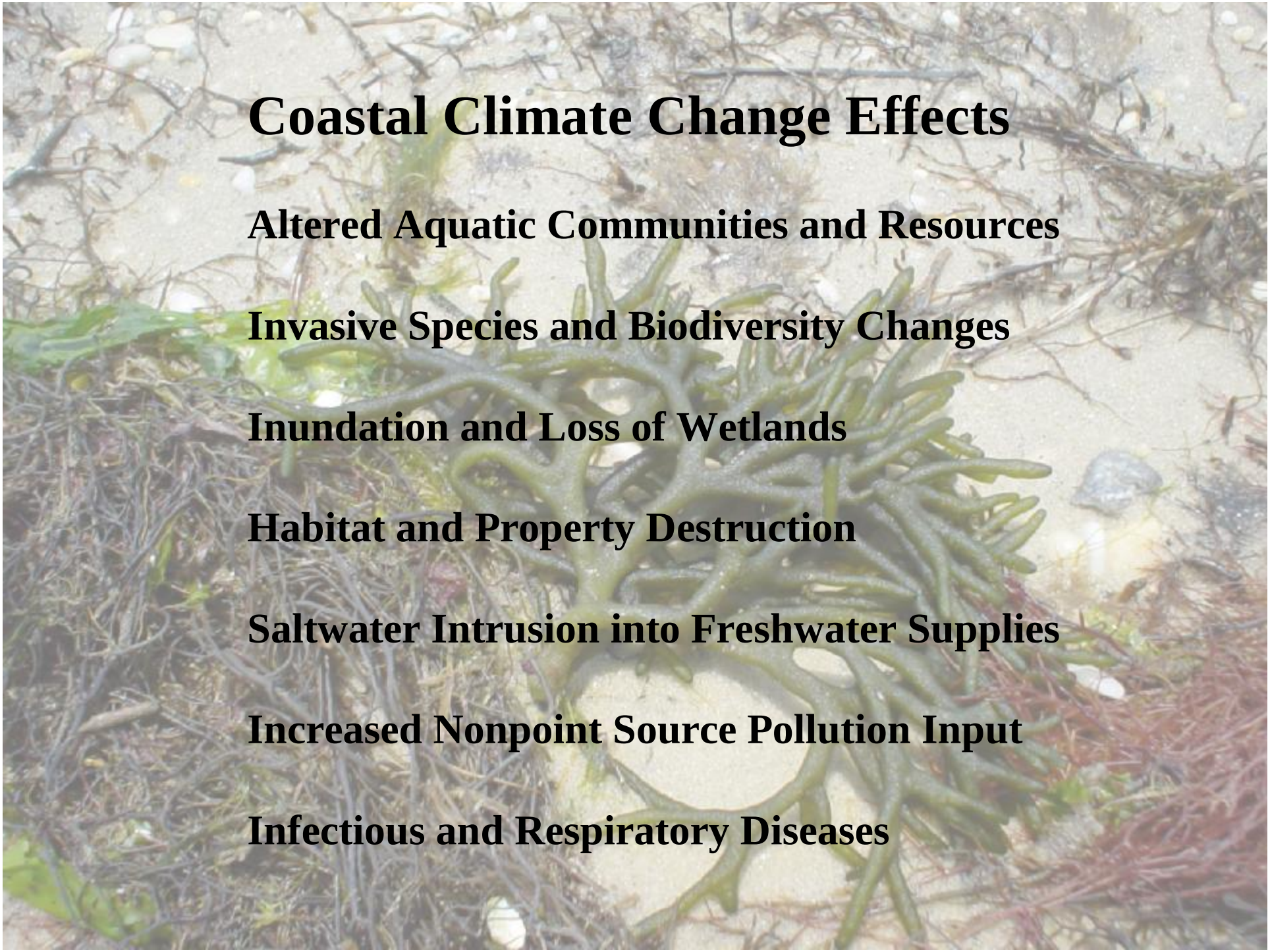
TRACKING FAUNA

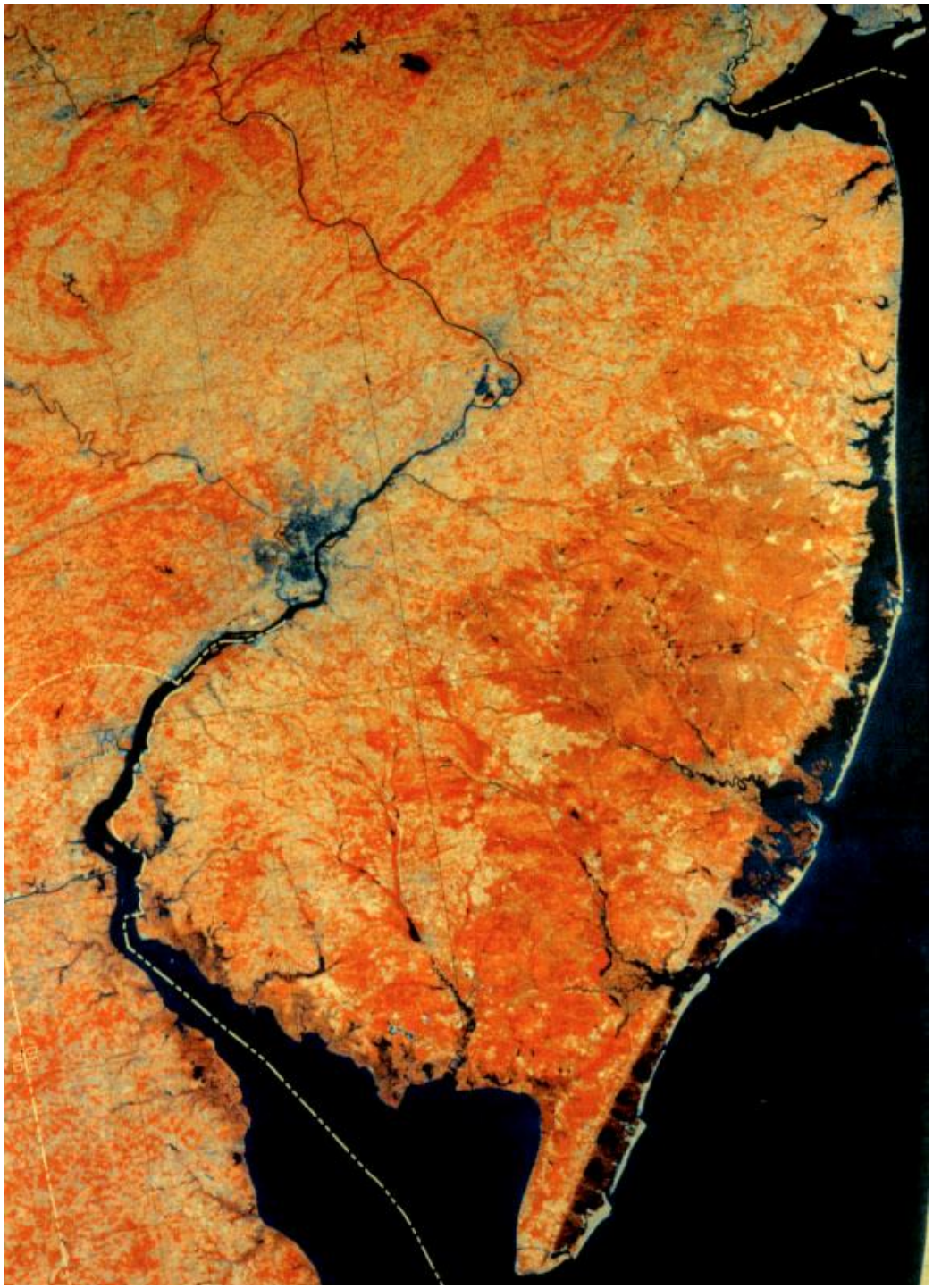
BIRDS

MAMMALS

REPTILES

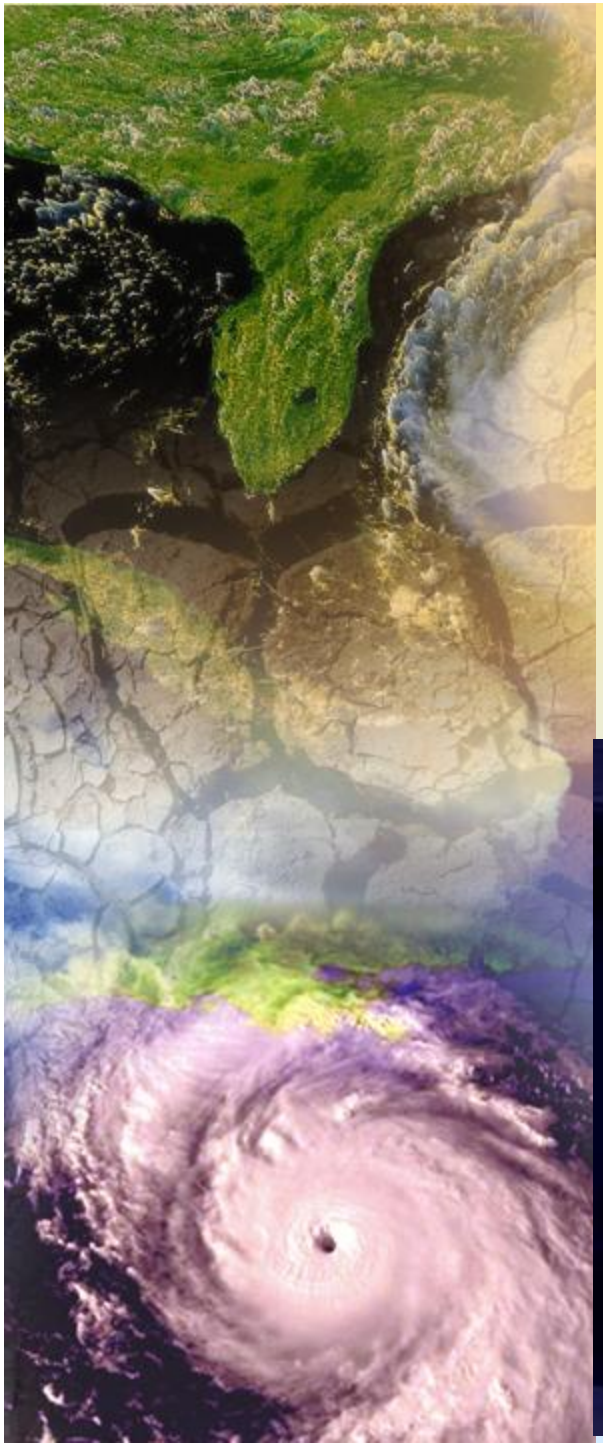
INSECTS


Coastal Climate Change Effects
Altered Aquatic Communities and Resources
Invasive Species and Biodiversity Changes
Inundation and Loss of Wetlands
Habitat and Property Destruction
Saltwater Intrusion into Freshwater Supplies
Increased Nonpoint Source Pollution Input
Infectious and Respiratory Diseases



Rutgers

Climate
and
Environmental
Change
Initiative
(CECI)

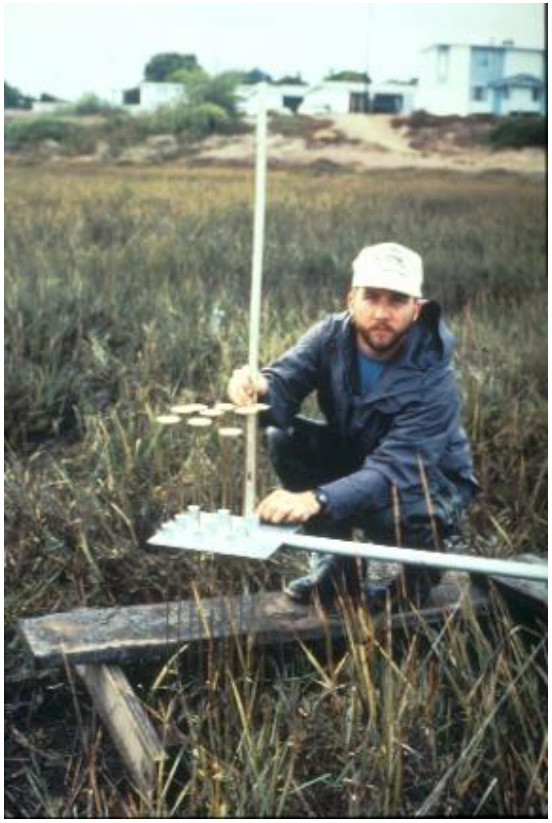


What Can Be Done To Reduce Impacts?

Combination Of Mitigation & Adaptation

Adaptation

Use Adaptive Management With Strong Monitoring Strategies



NERRS Multifaceted Role

- **SWMP Water Quality Monitoring Network**
- **Meteorological Monitoring**
- **Telemetry Capability and Data Delivery**
- **IOOS**
- **NERRS Habitat Mapping**
- **Enhanced GIS Watershed Data Inventory**
- **Climate Change/Sea Level Rise Initiatives**
- **Land-Margin Ecosystem Assessment**
- **Education and Outreach (Green Programs)**
- **Coastal Resource Management**

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Functions and linkages of land-margin ecosystems

Ecosystem vulnerability to climatic stressors

Water quality and aquatic stressors

Integrated ocean observing systems

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The End